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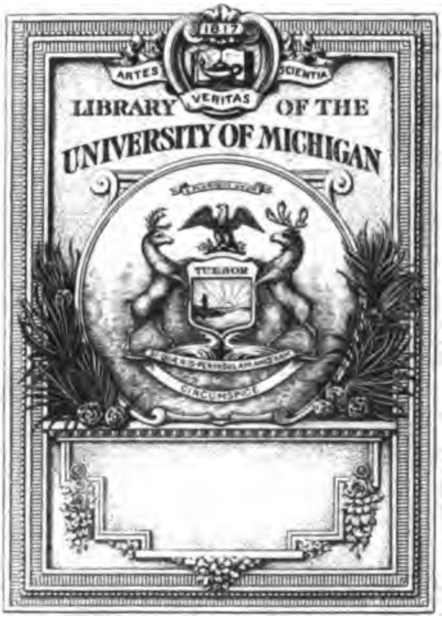

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WESTERN AUSTRALIA.

GEOLOGICAL SURVEY.

BULLETIN No. 71.

THE GEOLOGY AND MINERAL RESOURCES OF THE YILGARN GOLDFIELD.

PART III.

THE GOLD BELT NORTH OF SOUTHERN CROSS INCLUDING WESTONIA.

BY

T. BLATCHFORD, B.A., and C. S. HONMAN, B.M.E.,

ALSO

Notes on the Minerals of Westonia,

BY

E. S. SIMPSON, B.E., B.Sc., F.C.S.,

And Petrological Notes by

R. A. FARQUHARSON, M.A., (Oxon.), M.Sc., F.G.S.

ISSUED UNDER THE AUTHORITY OF
THE HON. R. T. ROBINSON, K.C., M.L.A., MINISTER FOR MINES.

WITH NINETEEN PLATES AND SEVENTY-FIVE FIGURES.

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PREFATORY NOTE.

The present publication forms one of a series of general reports dealing systematically with the geology and mineral resources of the gold and mineral fields of Western Australia. Separate descriptive reports on more or less isolated individual centres have appeared at intervals, and it was realised that the time has arrived when it became possible to undertake the preparation of reports, combining the general results of the departmental work, and presenting a systematic compendious account of the geological features and mineral and allied resources of each of the fields of the State. Reports of this nature will appear from time to time as the requisite investigations are completed, but not necessarily in geographical sequence. The goldfields of the State, as legally defined by the authorities, bear no relation to the geological boundaries, and are not all of the same area, nor do they all contain mining centres of equal importance, so that it will be found that the series of areal reports of necessity differ very materially in size.

In the preparation of such areal reports an attempt has been made to meet the special requirements of the mining community. It has already been pointed out that few mines on any mineral field present data sufficient to enable an accurate mental picture of the real nature of an ore deposit to be obtained, for such can only be arrived at by careful and systematic investigation into the geological structure and stratigraphy of wide stretches of country, where all the mineral deposits are perhaps genetically connected and capable of throwing light one upon another. Work of this special nature comprises, *inter alia,* the accurate mapping of the different geological formations, a correct understanding of the geological structure, the accumulation of information relating to the occurrence of the ore deposits, and their mode of formation. In the search for new deposits, and in defining the limits of those already known, the geologist has, to a large extent, to be guided by an understanding of the methods by which particular ore bodies have been formed, for it is only with this knowledge that the peculiarities of their distribution and the possibility or otherwise of their continuity can be forecasted.

These areal reports, when completed will, it is hoped, give both to the geologist, the mining engineer, the prospector, and others interested in the exploitation of the mineral resources of the State, along legitimate lines a comprehensive view of those salient geological features which have any bearing upon economic questions.

This bulletin marks the third of the series relating to the Yil-

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garn Goldfield, and completes the general description of that area. It includes an account of the country to the north of the Eastern Railway and embraces the whole of the northern portion of the Yilgarn Goldfield, as legally defined by the authorities; brief reference is also made to the extension of the Yilgarn gold belt lying to the south of Mount Holland and extending to the Phillips River Goldfield.

The area dealt with in this bulletin comprises about one hundred and sixty miles in length and ninety in width; it includes the principal mining centres of Corinthia, Bullfinch, Golden Valley, Mt. Jackson, Marda, and Westonia, together with the Koolyanobbing and Forrestania centres.

The field work in connection with this portion of the goldfield was carried out, with several unavoidable interruptions, by Messrs. Blatchford and Honman during the years 1914, 1915, and 1916. The area surveyed in such detail as circumstances warranted amounts to about 14,400 square miles. The country embraced by the survey falls within sheets 24 and 35 of the 300-chain series, issued by the Department of Lands and Surveys. The field work having been completed in August, 1916, it follows that mining developments since the officers left the field are not available for description.

The chief interest in the Yilgarn Goldfield centres in the auriferous deposits, which form three belts, trending generally north-west, rather than the more general problems of geology of which it however presents very many calling for much detailed research.

It seemed that legitimate assistance to private enterprise could be rendered in the direction of mapping and otherwise investigating the gold-bearing formations in the hope of furnishing a more or less reliable working guide for the use of the prospector and the mining engineer on the ground. The large scale, 40 chains per inch geological maps, of which there are now seven continuous sheets (viz., Bull. 49, Plate IX.; Bull. 63, Plates II., III., IV.; and Bull. 71, Plates VI., VII., and VIII.) present in the most convenient form the salient geological features adjoining the auriferous ore bodies of the whole of the Yilgarn Gold Belt. From these it will be seen that the Gold Belt is in reality a linear system of interrupted and overlapping veins, arranged more or less *en échelon*.

The Yilgarn field, as one of the important goldfields areas, comprises in its geology and mineral resources much that is typical of the entire Interior Plateau, and exhibits considerable diversity in geological constitution.

The gold-bearing belts may be designated, for convenience of description:—

(a.) The Yilgarn Gold Belt: this, which has a length of over one hundred miles, enters the goldfield on the southern boundary of the field, near Mount Ironcap, and passes through Mount Holland, Cheriton's, Parker's Range, Marvel Loch, Southern Cross, Corinthian, Bullfinch, Golden Valley, and terminates near Ennuin.

(b.) The Mount Jackson and Bungalbin Belt is the most northerly of the gold-bearing areas, and has a longitudinal extent of a little over thirty miles and a general trend of north-west and south-east; and

(c.) The Westonia Belt, which is an isolated area, lying about 35 miles to the west of the main or Yilgarn Gold Belt. It includes Boodalin, and its length so far as is known does not exceed twenty three miles, whilst its width is about five miles.

The figures giving the mineral production have been compiled from the data furnished by the statistical branch of the Mines Department; these which give the production of the various mining centres included within the confines of the field, show that up to the end of 1916 the Yilgarn Goldfield has returned 756,481.84 fine ozs. of gold obtained from the milling of 1,652,337.97 tons of ore.

Table showing the Total Yield of the various Mining Centres of the Yilgarn Goldfield up to December, 1916.

——	Ore Crushed.	Gold therefrom.	Silver.
	Long Tons.	Fine Ozs.	Fine Ozs.
Blackbourne	1,282·50	341·37	..
Bullfinch	248,781·59	117,768·93	16,442·43
Corinthian	134,581·50	29,167·15	..
Ennuin	235·06	421·92	..
Golden Valley	7,235·06	7,440·14	2·00
Greenmount	109,355·50	27,469·70	944·50
Hope's Hill .. .	131,489·55	35,486·95	1·00
Kennyville	23,445·35	12,636·99	·09
Koolyanobbing	363·00	127·98	..
Marvel Loch	303,469·25	99,115·33	771·03
Mount Jackson	38,181·78	28,334·50	2,305·28
Mount Rankin	666·00	176·55	..
Parker's Range	28,901·75	14,227·89	..
Southern Cross	434,052·30	211,724·08	364·11
Weston's	190,171·50	138,219·07	19·58
Goldfield generally, N.E.I.	126·28	33,823·29	36·54
Total	**1,652,337·97**	**756,481·84**	**20,886·86**

It is probable that these figures do not accurately represent the yield of the Yilgarn field, for in the early days of mining in Western Australia, a great deal of the gold won was probably never officially reported to the Department of Mines, and deemed worthy of no better record than the ephemeral currency of the newspaper. No silver has been mined in the Yilgarn field, its occurrence being incidental to the output of gold. The total amount of silver produced up to the end of 1916 is only 20,886.86 fine ozs.; it occurs, however, at nearly every mining centre, though in many cases the amount is so small as to be almost negligible.

Full descriptions, illustrated in many cases by plans and sections, are given of the mines in active operation, or otherwise accessible, as occurred in the area embraced by the field work of Messrs. Blatchford and Honman.

The geological plans and sections of the underground workings, which accompany the report, have been based on the plans which the various mine owners lodge with the Department of Mines in compliance with the Mines Regulation Act.

A high grade deposit of iron ore occurs in the Koolyanobbing Range, near Lake Seabrook, associated with the ferruginous quartzites (Jaspilite) which forms the backbone of the range. The ore which consists of a lens of micaceous hematite proves to be some of the purest yet found in the State.

A Gibb Maitland

GOVERNMENT GEOLOGIST.

Geological Survey Office, Perth,
1st September, 1917.

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PART A.

THE GEOLOGY AND MINERAL RESOURCES OF THE YILGARN GOLDFIELD.

By

T. BLATCHFORD, B.A.

THE GOLD BELT NORTH OF SOUTHERN CROSS, INCLUDING WESTONIA.

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Location
Roads
Geology of the Field
The Leases
Water Supply
Mines
Reward Mine
Lady Lyons Mine
Great Southern No. 1 Mine
Commonwealth Mine
Premier Mine
Black Prince Mine

I.—INTRODUCTION.

Bulletins Nos. 17, 49, and 63,* already issued, have dealt with the geology of the portion of the Yilgarn Goldfield lying to the south of the Great Eastern Railway and a small area extending from Southern Cross township northwards to Hope's Hill.

The following pages are confined to a description of that portion of the Yilgarn Goldfield extending from the railway line to the northern boundary, with a brief reference to the country extending past the southern boundary into the Phillips River Goldfield, which is really a continuation of the southern portion of the auriferous Yilgarn belt.

Owing to the extensive area to be examined the mapping was divided into two sections with the intention, if possible, of writing the final report conjointly after a general inspection of the whole area under review.

The northern section embracing the country from Trough Well to the northern boundary and including the Koolyanobbing belt was, however, done exclusively by my colleague, C. S. Honman, whose completed and independent report is included in the following pages, for owing to the exigencies of the office work the original idea of a conjoint report had to be abandoned.

The balance of the field work was done exclusively by the present writer.

Camp was first pitched in May, 1914, and the whole of the field work was practically ready for writing up in July, 1915, when orders were received to inspect a reported gold find 100 miles south of Southern Cross. Subsequently, further orders were received to become attached to Mr. McIntyre's prospecting party as consulting geologist.

In May, 1916, owing to the length of time intervening, it was necessary to re-inspect the whole of the mining operations. The field work was eventually completed in August, 1916.

For the mapping of the general geological features a scale of 300 chains to one inch has been used. Along the auriferous belt, however, where more accuracy was warranted, 20 chains to one inch was the scale used, while for underground mining work scales of 30, 40, or 60 feet to one inch were adopted.

The present Bulletin completes the survey of the Yilgarn Goldfield, and should be read in conjunction with Bulletins 17, 49, and 63, which are detailed descriptions of the southern areas.

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* Bulletin No. 17, by C. C. Gibson. Perth: By Authority, 1904. Bulletin No. 49, by E. C. Saint-Smith and R. A. Farquharson. Perth: By Authority, 1913. Bulletin No. 63, by T. Blatchford. Perth: By Authority, 1915.

II.—PREVIOUS GEOLOGICAL INVESTIGATIONS.

The following is a list of departmental reports on the whole or portions of the Yilgarn Goldfield:—

(a) Annual Report of the Government Geologist, 1888-1889.

(b) Annual Report of the Government Geologist, 1890.

(c) Report of the Government Geologist, 1892. Parliamentary Papers No. 12 of 1893.

(d) Report on Central Goldfields. Appendix, Parliamentary Papers No. 8, 1894.

(e) Report on the Yilgarn Goldfield. Parliamentary Papers No. A4 of 1891. By H. P. Woodward, Government Geologist.

(f) Report on the Interior Gold Region of Western Australia. By S. Göczel. Perth: By Authority, 1894.

(g) Mining Handbook to the Colony of Western Australia. By H. P. Woodward, Government Geologist. Perth: By Authority. 1st Edition, 1894; 2nd Edition, 1895.

(h) Report on the Mines of the Yilgarn Goldfield. By A. Montgomery, M.A., F.G.S., State Mining Engineer. Perth: By Authority, 1908.

(i) Geology and Auriferous Deposits of Southern Cross, Yilgarn Goldfield. By Chas. G. Gibson, B.E. Perth: By Authority, 1904.

(j) A general description of the Northern portion of the Yilgarn Goldfield and the Southern portion of the North Coolgardie Goldfield. By H. P. Woodward. Perth: By Authority, 1912.

(k) Geology and Mineral Resources of the Yilgarn Goldfield, Part I.—Southern Cross. By E. C. Saint Smith, A.S.T.C., and R. A. Farquharson, M.A. (Oxon.), M.Sc., F.G.S., with Chemical Notes by E. S. Simpson, B.E., B.Sc., F.C.S. Perth: By Authority, 1913.

(l) The Geology and Mineral Resources of the Yilgarn Goldfield, Part II.—The Gold belt south of Southern Cross. By T. Blatchford, B.A., with Petrological Notes by R. A. Farquharson, M.A. (Oxon.), M.Sc., F.G.S., and Mineralogical Contributions by E. S. Simpson, B.E., B.Sc., F.C.S., and A. J. Robertson, M.Sc. Perth: By Authority, 1915.

Of the foregoing, Woodward is the only writer who has touched on the general geology of the portion of the field under review, the other reports deal with the southern or Southern Cross areas only, or are descriptions of individual mines.

III.—HISTORICAL.

Records show that the portion of Western Australia now known as the Yilgarn[*] Goldfield was traversed as early as the year 1846, when A. E. and R. T. Gregory passed through Mount Jackson on their journey to Menzies.

Two years after this, in September, 1848, Roe reached the Bremer Range immediately to the south of the Southern boundary of the goldfield.

B. D. Clarkson, C.E., A. Dempster, and C. Harper traversed the Yilgarn Hills in the year 1861.

In 1864 Hunt passed over portion of the same country on his way to Coolgardie.

The primary object of these exploring parties was not so much the search for minerals as for pastoral areas and, hence, we do not read of their finding any gold or of their making any systematic search for the same.

The Government, in 1862, to stimulate a searching for gold and base metals, offered a reward of £5,000 for the discovery of a payable goldfield within a radius of 50 miles from Perth. In 1869 the distance was extended to one of 300 miles.

The first real impulse to prospect for gold east of Perth was given by the discovery of a small speck of gold found in 1887 by a Mr. Glass, at Mowjakine, whilst excavating a tank near his homestead.

This discovery, though insignificant in itself, led to the forming of a gold prospecting party under the leadership of one Bernard Colreavy.

Colreavy's first expedition met with little success. The country he traversed was between Newcastle and the Wongan Hills.

However, on his second trip he set out towards the Yilgarn Hills.

Whilst he was in the field on this second trip another party, under the leadership of Anstey, returned with some rich specimens of gold in quartz found at Eenuin. Shortly afterwards Colreavy returned with specimens of gold-bearing quartz from Golden Valley.

These discoveries caused a rush of prospectors, and one party, known as the Phoenix,[†] whilst travelling south from Golden Valley, found the permanent reefs at Southern Cross, afterwards known as Fraser's Gold Mines.

Discoveries soon spread north and south of Southern Cross, in fact, Southern Cross became a busy centre from which prospectors went farther afield to meet with the successes they deserved in opening out the still richer fields to the east. The rapidity of these discoveries is evidenced by the dates of opening of railways: Southern Cross, 1st July, 1894; Kalgoorlie, January, 1897.

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[*] *Yilgarn*—aborigine for *quartz*.

[†] The Phoenix party comprised Messrs. T. Risley, Michael Toomey, and Charles Crossland. The date of their original discovery was January 21st or 22nd, 1888.

Unfortunately, there are no reliable records of the amounts of gold won in individual years prior to 1897.

The total amount recorded from the Yilgarn Goldfield to 31st December, 1896, is 174,325 tons for 93,456 ounces. With the exception of 29,000 tons from Hope's Hill gold mine, 1,500 tons from Mount Jackson, and 166 tons from other sources, the whole of this ore came from Fraser's reefs at Southern Cross.

The following table shows the progression and retrogression of the yearly outputs from the year 1897 to 1915:—

Output of Gold for the Yilgarn Goldfield from the year 1897 *to the year* 1916 (*inclusive*).

Year.	Ore treated in long tons.	Gold therefrom in ozs.	Remarks.
Prior to—			Value per oz. £ s. d.
1897	174,925	93,456	..
1897	35,988	17,072	..
1898	27,807	11,769	..
1899	33,403	16,371	..
1900	54,403	29,155	..
1901	25,529	26,564	3 10 0¾
1902	41,218	23,115	3 13 3
1903	50,623	23,403	3 8 10½
1904	66,051	25,461	Fine gold.
1905	47,965	19,284	,, ,,
1906	64,763	23,464	,, ,,
1907	50,833	19,263	,, ,,
1908	54,047	22,149	,, ,,
1909	44,337	20,879	,, ,,
1910	34,114	27,785	,, ,,
1911	18,897	18,678	,, ,,
1912	73,199	30,633	,, ,,
1913	154,495	82,226	,, ,,
1914	211,453	88,714	,, ,,
1915	205,331	91,092	,, ,,
1916	181,949	87,930	..
Total, to end of 1916 ..	**1,652,340**	**756,481***	..

From the foregoing figures it is obvious that there was a gradual falling away of the gold production up to the year 1912, when, after that year, there was a very pronounced increase. This increase was, undoubtedly, due to a phenomenal revival of mining during the years 1910 and 1911.

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* Total return in fine ounces excluding alluvial 89·88ozs., and 1,394·70 ounces dollied.

In the latter part of 1909 a discovery of gold was made at a spot now known as Bullfinch, which became one of the most noted in the history of mining in Western Australia. The name of the discoverer was Charles Jones, the representative of a prospecting syndicate formed by Messrs. D. L. Doolette and party. Jones' original application for leases was made on the 29th of December, 1909. The leases were situated about 22 miles north-west of Southern Cross, and are now known as the Bullfinch Proprietary group. The sequel to the first rich crushings from these leases was the applying for old and neglected mines and the prospecting for new mines throughout the whole field. Hence such mines as the Mountain Queen and Corinthian North were capitalised and turned into regular gold producers. The Mount Jackson and Marda centres were also revived.

In addition, an impetus was given to prospect farther afield. Thus we find applications for Weston's Reward on 12th December, 1910; the Recovery, 29th December of the same year; the Myrtle Central (now Edna May Central) early in the following year, and many others too numerous to name. This portion of the field's history is very significant and demonstrates clearly how a mining centre can almost pass into oblivion and be suddenly resurrected by one sensational discovery.

Suffice it to say that of the total production for the year 1914, the output from five mines only, which undoubtedly owed their development to the Bullfinch discovery, was 180,836 tons, yielding 71,874 ozs. fine gold.*

EXTENT AND BOUNDARIES OF THE YILGARN GOLDFIELD.

In the *Government Gazette* publish on 28th January, 1916, the following boundaries were fixed for the Yilgarn Goldfield:—

Bounded by lines starting from a point north of Cairn H26 on Koorarawalyee rock and west of Cairn NB1 at Wangine Soak, and extending south along the west boundary of the Coolgardie and Dundas Goldfields, and passing through Cairn H26 at Koorarawalyee rock to a point east of the summit of Mount South Ironcap; thence west, passing through the summit of Mount South Ironcap to a point on the southern section of the No. 1 Rabbit-proof Fence near the 113-mile post; thence north-westerly and northerly along the fence to the 14-mile post on the northern section of the fence; thence east 20,833 links, north 24,000 links, and west 20,833 links to the 17-mile post on the fence; thence northerly along the fence to the 158-mile post; thence easterly about 75 miles to a Cairn marked AN11 on an island at the eastern end of Lake Barlee; thence southerly about 11 miles to a Cairn marked GDR40 on Mount Elvire; thence south-south-easterly about 41 miles to Johnston's rocks; thence south-easterly about 26 miles to starting point.

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* During the years 1912 and 1913 these mines were busy erecting plants and developing ore.

IV.—PHYSICAL FEATURES.

The physiographical features of the northern portion of the field have already been described in detail by my colleague in his report on the Mount Jackson District.

In the south-western section of the area under review there is little relief in the surface features.

Viewed from any of the higher points, the general aspect is one of a vast undulating plain from which rise comparatively insignificant ridges, the highest points of which, such as Koolyanobbing and Bundalbin, stand out in bold contrast. Occasional isolated granite knobs, like Yorkrakine and Baladjie, also form good landmarks.

The dry lakes are usually found following round these ridges and higher points.* Jutson has included this area in his central or salt lake division,† and described it as an elevated plateau of arid erosion, the present surface being mainly the planed surface of the old plateau.

Taking the railway levels as indicative of the average height above sea level on an east to west section, we find the minimum height above sea level is 1,060 feet, with a maximum of 1,343 feet, a difference in elevation only of 283 feet in a distance of 81 miles.

The highest portions in this section are due to ridges running in a general north-north-west-south-south-east direction.

Of these, the first crosses the railway at Noongar and extends north-westward past Warrachoppin, on to the Rabbit-proof Fence.

The other passes through Southern Cross, Bullfinch, on to Ennuin.

From Karalee eastwards there is a general and decided increase in elevation of from 100 to 200 feet, the maximum being reached at Koorarawalyee, 1,522 feet.

The "old plateau" is not extensively represented, and most of the remnants of the older land surface are to be found in the middle western area. Middle Double Gunyan is one of the best examples. There we find a flat-topped ridge, with the characteristic "breakaway" weathering well represented.

The isolated granite knobs, Yorkrakine, Baladjie, and Karolin rocks, may also be considered as further remnants.

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* *Vide* Plates I., II., and III.

† Bulletin 61,—Physiographical geology of Western Australia. Perth: By Authority 1914.

Of the greenstone areas, the Yilgarn Hills, apparently, though they do rise from areas of depression, may still be regarded as portions of the old plateau. There is little doubt that they owe their presence to their greater weather-resisting properties, due to their composition, and particularly to the prevailing quartz haematite ore which is a typical feature.

In the Golden Valley area isolated hills of quartz conglomerates have also defied denuding agencies and, in consequence, remain as fairly conspicuous monadnocks.

RIVERS.

Rivers are absolutely non-existent, and except, perhaps, immediately after the heaviest rainfalls, there is practically no flow of water at the surface.

Surrounding the lakes minor watercourses have been cut by storm water falling on the bare hills, but such are too insignificant to deserve further notice. Under normal conditions there is no flowing water at the surface.

LAKES.

A very extensive "dry" lake system occurs in the centre of the northern Yilgarn field, extending from Southern Cross northwards to Mount Jackson, the extent of which is clearly shown on Plate 1.

As their name would imply, the lakes in this system are usually dry, and even with their maximum quantity of water seldom attain a depth of more than a few inches, and that only after heavy rainfalls.

With regard to the deposits in these lake beds the information is, unfortunately, most meagre. Some of the lakes have undoubted rock floors, which are bare of deposits. Examples of this may be found in Lake Seabrook where crossed by the greenstone at Koolyanobbing,* and a portion of Lake Deborah, near Marie's Find.†

In both the foregoing instances greenstone forms the floor of the lake, which may account for the absence of any deposits, for where the basins are resting on granite the conditions are different, the floors being soft and boggy.

Probably this is due to the granite being more easily weathered rather than to the accumulation of detritus carried from a distance, a point which is still obscure owing to the fact that the lake floors have never been pierced by bores or shafts. That the denuded surface of the floors is robbed of its detritus by wind action is evident, for round the lake edges are usually to be found large deposits of sand in the form of sand dunes, and in several instances even extensive deposits of seed gypsum. The seed gypsum is without doubt derived from the breaking up of the crystals by wind, the crystals, in the first place, being deposited on the lake floors from the water concentrated by evaporation. At the present day it is not at all uncommon to find gypsum crystals in the mud of the lake floors and, at times, scattered over the dried surface.

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* Plate XVIII. † Plate VII,

Furthermore, it is interesting to note the directions from which the prevailing winds blow by studying the sides of the lakes on which these sand and gypsum deposits occur.

As a general rule, with, of course, minor exceptions, it will be found that the deposits occur on the southern or south-eastern edges of the lakes, the western and northern shores being usually bare rock floors, or covered with very thin deposits. In consequence, the northern and western shores are usually more or less precipitous, more particularly so when they abut on the greenstones.

From the foregoing, the natural deduction is that the lakes are migrating westward.*

One of the best examples of the foregoing lake characteristics is to be seen at Marie's Find. Marie's Find is on a peninsula jutting out north-eastwards into Lake Deborah. The northern side of the peninsula is a succession of sand dunes, whilst the southern side is precipitous, bordering a rock floor bare of sand. Numerous islands rise up from the basin far out in the lake, illustrating the migration, whilst the southern shore of Lake Deborah forms another instance of the sand dune formation.

V.—CLIMATE.

The climate is intensely hot and dry in the summer months, with usually cold, bleak, but bracing weather in the winter.

As may be seen from the accompanying meteorological tables the highest shade temperature recorded was in January, 1910, when the thermometer rose to 115°, whilst the lowest record was 25°, the latter registration occurring in August, 1900, June, 1908, and July, 1902, 1906, and 1914. The average rainfall, taken for a period extending over 26 years, is 994 points (100 points representing one inch), the maximum for one year being 1,957 points in 1915, and the minimum 512 in 1894. The three wettest months are June, July, and August.

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* *Vide* Plate VI.

Shade Temperature for Southern Cross.

(Means for 18 years.)

	Mean Max.	Mean Min.	Mean.	Highest Max.	Date.	Lowest Min.	Date.
January	95·1	62·3	78·7	115·0	1910	44·0	1899
February	92·8	62·1	77·4	112·0	1900	46·0	1905
March	87·4	57·2	72·3	107·9	1906	38·2	1910
April	79·2	51·1	65·4	101·1	1906	30·0	1914
May	69·2	44·9	57·0	92·0	1914	26·0	1914
June	62·8	41·2	52·0	79·0	1912	25·0	1908
July	61·8	39·0	50·4	75·3	1906	25·0	1902 1906 1914
August	65·3	40·9	53·1	95·9	1907	25·0	1900
September ..	71·9	43·4	57·6	92·3	1914	26·0	1908
October	78·1	48·4	63·2	102·0	1914	33·0	1909
November.. ..	87·0	54·9	71·0	110·2	1913	35·6	1907
December ..	93·1	60·3	76·7	114·6	1908	41·0	1913
Year	78·6	50·5	64·6	115·0	Jan. 1910	25·0	August 1900 July, 1902 July, 1906 June, 1908 July, 1914

Rainfall for Southern Cross, W.A.

Year.	Jan.	Feb.	Mar.	April	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1889	59	4	*Nil*	46	224	227	170	88	101	59	39	*Nil*	1,017
1890	..	..	..	..	..	35	121	73	88	92	53	25	..
1891	*Nil*	*Nil*	21	3	145	135	100	22	50	24	*Nil*	23	523
1892	62	4	417	86	266	41	252	179	79	119	25	40	1,510
1893	71	19	128	142	347	144	159	83	70	16	48	177	1,404
1894	63	18	108	4	37	46	80	69	42	5	19	21	512
1895	4	10	2	17	81	168	61	155	42	2	*Nil*	*Nil*	542
1896	73	19	316	*Nil*	28	66	225	55	14	15	89	178	1,078
1897	11	69	59	4	29	233	68	114	34	6	1	107	735
1898	1	145	*Nil*	3	75	251	65	193	14	93	23	*Nil*	863
1899	4	12	*Nil*	4	12	158	142	55	89	55	226	*Nil*	757
1900	55	12	25	260	224	129	54	73	59	171	40	27	1,129
1901	*Nil*	39	45	10	133	143	108	189	49	7	12	3	738
1902	105	254	33	*Nil*	94	128	115	83	93	54	45	17	1,021
1903	*Nil*	70	*Nil*	113	96	126	116	75	112	81	53	60	902
1904	14	*Nil*	165	2	229	262	262	59	418	187	59	88	1,745
1905	43	54	*Nil*	27	185	30	97	45	85	54	8	105	733
1906	3	98	*Nil*	5	225	99	193	199	28	7	55	50	962
1907	35	12	199	16	62	86	339	79	84	3	12	17	944
1908	*Nil*	25	35	212	176	107	110	59	32	28	88	11	883
1909	78	53	4	254	79	266	56	346	22	47	20	*Nil*	1,225
1910	22	119	3	2	219	232	258	92	63	120	31	*Nil*	1,161
1911	70	40	20	25	147	38	135	49	28	28	*Nil*	10	554
1912	97	41	50	127	266	24	239	21	74	42	60	143	1,184
1913	7	*Nil*	83	87	40	107	107	220	181	87	22	137	1,078
1914	38	7	*Nil*	28	*Nil*	54	85	83	*Nil*	226	134	32	687
1915	389	306	58	123	350	174	246	162	77	30	*Nil*	42	1,057

VI.—DESCRIPTIVE AND ECONOMIC GEOLOGY.

The geological features of the northern section of the Yilgarn Goldfield readily lend themselves to a general classification into four main parallel belts of greenstones and their associated rock formations, surrounded by a vast area of massive granite. Taken consecutively from north to south, these are referred to for descriptive purposes, in the following pages, as the Mount Jackson, Marda, Koolyanobbing, Southern Cross, Bullfinch, and Westonia belts. My colleague has written a full report on the Mount Jackson, Marda, and Koolyanobbing areas, and such will be found included in the present Bulletin.

The following observations will be confined to the Bullfinch and Westonia areas.

VII.—PREVIOUS GEOLOGICAL OBSERVATIONS.

Despite the fact that gold was first found on the Eastern Goldfield in the Bullfinch belt, the discovery was soon eclipsed by more important and richer finds further afield. Hence the Yilgarn field was for a considerable time neglected by the mining world.

However, when the Bullfinch mine was opened up and mining in the district revived, fresh interest was taken in the field. Up to this time the only departmental officer to report on the mining of the Bullfinch belt was H. P. Woodward*, who visited Golden Valley shortly after the first discovery on 22nd January, 1888.

In the year 1912 Woodward made a reconnaissance survey of the Bullfinch belt and the country lying to the north, with the object of ascertaining the extent of the Bullfinch belt and the possibility of locating others of a similar nature.†

It should be noted that prior to this survey others had been made of the southern portions of the Yilgarn Goldfield. Thus we have a report by Gibson on Southern Cross,‡ one by Saint Smith and Farquharson§ on the same area, but in greater detail, and a subsequent one by Blatchford and Saint Smith¶ on the southern extremity of the belt extending from Southern Cross to Cheriton's. These should be read in conjunction with the present report, for though references will be made to these reports in the following pages, there is such a similarity in the geology that the full text should be perused. Of the Westonia belt, which is a comparatively new field, there is no available literature except an interim report by Blatchford, published in the year 1914.||

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* Annual Reports by Government Geologist, 1888–1889, 1890.

† Bulletin 46.—A general description of the northern portion Yilgarn Goldfield, by H. P. Woodward. Perth : by Authority, 1912.

‡ Bulletin 17, by C. G. Gibson. Perth : By Authority, 1904.

§ Bulletin 49, by E. C. Saint Smith and R. A. Farquharson. Perth : By Authority, 1913.

¶ Bulletin 63, by T. Blatchford and E. C. Saint Smith. Perth : by Authority, 1915.

|| *Annual Report*, Geological Survey, W.A., 1914.

VIII.—GEOLOGY OF THE BULLFINCH BELT.

On the frontispiece, and more particularly on Plates VI. and VII., the extent of the Bullfinch belt can be seen like a narrow "island" in a "sea" of granite.

In detail, the rocks of the belt are found to be essentially of basic igneous character in which occur remnants of a highly altered sedimentary series. Through the greenstones are found numerous acid or granitic dykes the apophyses of the surrounding granite. These are of a later age than the main basic rocks. At a very much later time basic intrusives burst through the granites and greenstones and such are now found as fresh narrow dykes (dolerites). Exclusively in the greenstones, and usually following the granite-greenstone boundary, are long lenses of quartz-haematite schists. It will be pointed out later on that these probably owe their origin to the greenstones being crushed by the action of the intruding granite (probably due to heating and contraction on cooling), and to the after alteration along these fissures by circulating underground solutions. Thus the crushed material has been replaced by silica and iron contained in the underground circulating waters.

Quartz reefs are found both in the greenstones and granite areas, being, in the latter case as a general rule, non-auriferous.

The geological age of the rock types is not known, except relatively to one another. The only rocks which could throw any definite light on this point are the sediments. Unfortunately, these have so far been proved to be unfossiliferous.

However, there is evidence to indicate that the metamorphic sediments are probably the oldest rocks of the field, and their lithological characteristics are such as to suggest an age far back in geological time. Placed in relative chronological order, the following rock species are represented. The order is placed starting with the oldest rocks first:—

1. Sedimentary (metamorphic) (non-auriferous).
2. Greenstones (massive igneous) (auriferous).
3. Granites, massive igneous (non-auriferous).
4. Quartz haematite schists and lodes (auriferous).
5. Quartz reefs (auriferous).
6. Acid or granitic dykes (seldom auriferous).
7. Quartz reefs (auriferous).
8. Greenstones (intrusive), dolerites (non-auriferous).
9. Laterites and superficial deposits (non-auriferous).

SEDIMENTARY ROCKS.

There are two well-defined developments of sedimentary strata in the Bullfinch belt. Of these the first is found striking northwest through the townsite of Bullfinch,* and from here it extends south to the 18-mile post on the Bullfinch-Southern Cross road. The total length is a little more than four miles with a maximum width of about 25 chains.

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* *Vide* Plate VII.

The second belt starts on the southern end at the 28-mile post and runs approximately parallel with the Jackson road, as far north as the 41-mile post, thus forming a belt of some 13 miles in length. The greatest width of the belt is found near Golden Valley where it measures on the surface about 60 chains.

A smaller belt lying to the east of the 42-mile post is probably a continuation of the second belt. The width of this third series is about 20 chains in the centre with a total length of 1¾ miles.

All three sedimentary beds are represented by fine-grained bands of phyllites (originally shales) and dark graphitic stained quartzites, whilst crushed quartz conglomerates are of frequent occurrence.

Fig. 1.

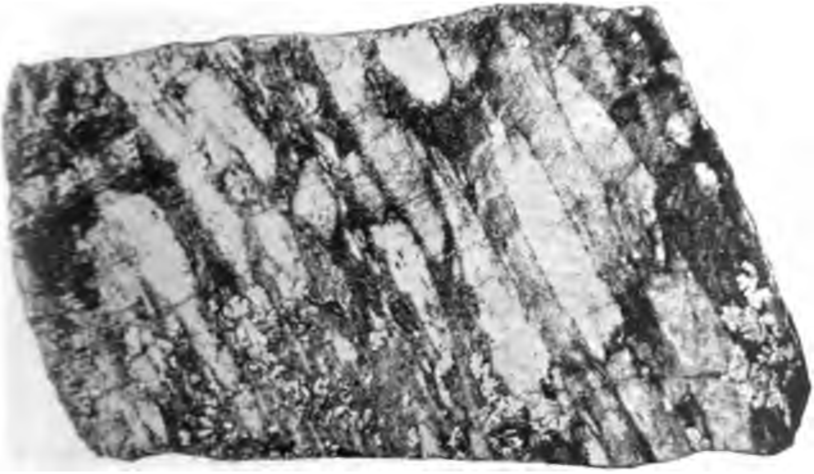


Photo: R. H. Irwin. **Crushed quartz conglomerate.** Neg. 1342.

Unfortunately, sections are rare, in fact good sections do not occur.

The absence of sections is, no doubt, due to the easy weathering of the soft shales and also to their being the prevailing type in the series. Furthermore, they are less resistant than the greenstones, and hence are usually found on the lower-lying ground, and covered over partially or completely by the detritus washed down from the greenstone hills. The portions composed of conglomerates, however, are sometimes seen forming detached hills (monadnocks).

This is more particularly the case about a mile north of Gol Valley. Here some of these crushed beds can be observed, and characters studied without difficulty.

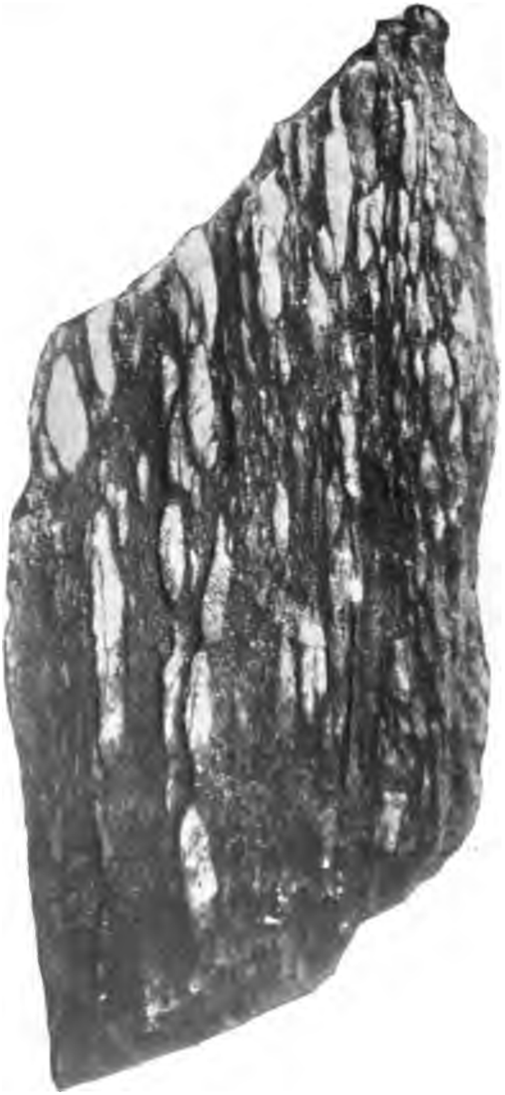


Fig. 2

Crushed quartz conglomerate.

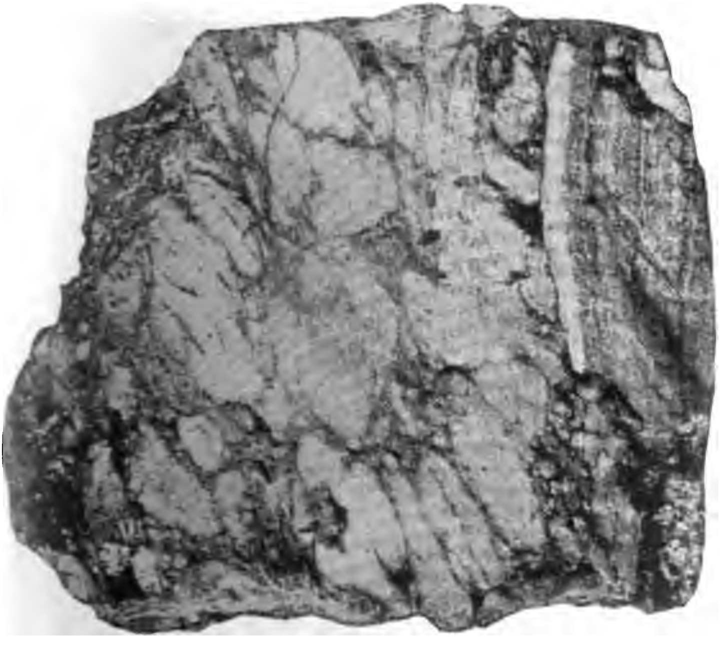
Neg. 1343.

Photo: T. Blatchford.

These beds consist essentially of quartz pebbles varying in size from four or five inches in length to the size of a pea. In almost every instance the pebbles have been elongated or drawn out by intense pressure.

A characteristic diagonal cracking is also very common. Both the cracks and elongation are well illustrated in Figures 1, 2, 3, and 4. The pebbles are held together by a siliceous cement, thus forming a hard, brittle rock, which would have resisted weathering much more than it has were it not for the extensive cracking of the pebbles, and also the fissuring of the rock *en masse*.

Fig. 3.



T. Blatchford. Neg. 1340.

Crushed quartz conglomerate.

Sections in some costeans at Bullfinch expose a dark, gritty rock, at times almost black in colour, but usually a very dark grey. Sections of this rock correspond almost entirely with those obtained from the Westonia sediments. The rock consists of an aggregate of quartz grains, the colouring being due to the presence of fine graphite dust. This rock has probably been a band of grit or coarse sandstone which has been crushed and impregnated with graphite. Only r sections can be seen of the phyllites or finer sedimentary bands. As a rule, the only specimens obtainable are small fragments scattered on the surface. In most instances they are found to contain andalusite crystals similar to those in the southern areas.* From their persistent occurrence at the surface there is every reason to believe that they form the major portion of the sedimentary deposits. The beds have a vertical dip with a general north-west south-east strike.

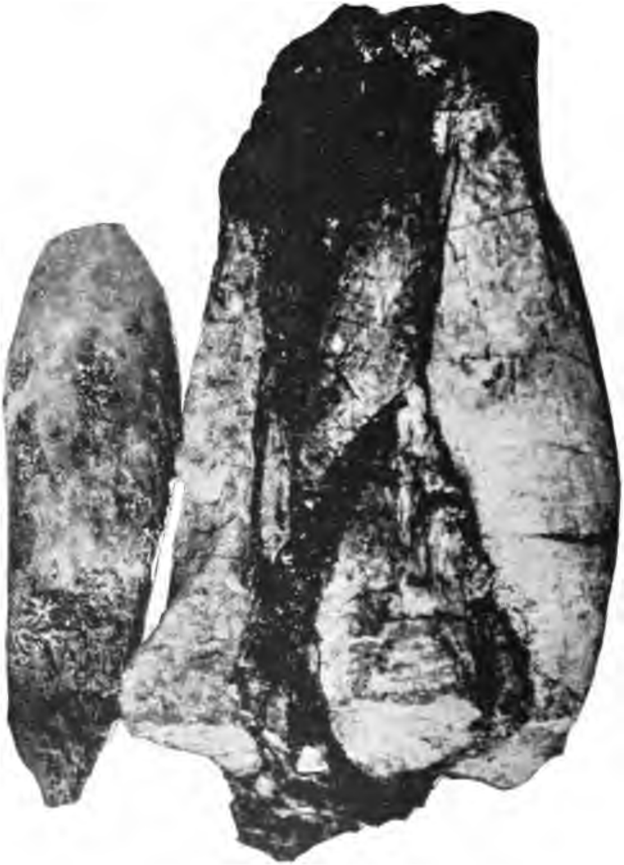


Fig. 4.

Elongated quartz pebbles from quartz conglomerate. Neg. 1341.

Photo: R. H. Irwin.

From an economic point they are of no importance, as in no single instance has gold been found in them in payable quantities, neither do they contain any of the base commercial minerals in such quantities as to warrant exploiting.

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* Bull. 63, p. 38. Perth: By Authority, 1915.

Certainly, in some instances, narrow bands of ironstone are seen outcropping along the strike of the beds, but these have been proved to be of such low grade in gold contents as to be worthless, and the iron contents are also poor and the tonnage insignificant for practical purposes.

The beds have a certain amount of importance purely in a geological sense, as they probably represent some of the oldest rock formations of the State, certainly of the Yilgarn Goldfield.

GREENSTONES (amphibolites).

The greenstones or basic igneous rocks of the Bullfinch belt are a continuation of the main rock-mass which passes through and extends southward past Southern Cross.

As several writers have already described the Southern Cross section of this belt, a *résumé* of their various opinions will be stated here, the reader being referred to the several publications in which the reports are to be found, for the detailed descriptions. Gibson,[*] who was the first to deal with the classification of the basic igneous rocks of the Southern Cross type, divided them into two classes:—

(a) The schists, (b) the massive and foliated variety.—Between these there is no hard and fast boundary, the former gradually passing into and being merely a highly altered form of the latter; moreover, it is often difficult to distinguish between them owing to the fact that at the surface the foliated variety often weathers into the form of schists, this weathering, as a rule, only reaching a few feet below the surface.

The schists are for the most part found in juxtaposition to the granite and evidently owe their existence to the presence of the latter.

The massive and foliated variety form the more western portion of the belt, and occupy a far greater area than do the schists, being generally prominent in the south-western portion of the district examined, where they form a series of low ridges having a general trend slightly west of north. These massive rocks vary considerably in their microscopic properties, passing in all stages from an exceedingly coarse-grained hornblende rock into fine-grained chlorite schists mentioned above.

Saint Smith[†] divides the basic rocks into two classes, the "older" and the "newer," regarding the former as "metamorphosed rocks, tuffs, etc."

Farquharson[‡] divides the rocks into two main classes, subdividing each class into several groups, thus:—

Class I.—Rocks composed of ferro-magnesian minerals without felspar or quartz.
  A.—Those consisting of pale-coloured hornblende occurring in confused aggregates.
  B.—Those in which hornblende occurs in compact grains—several are intermediate between A. and B., with both fibrous and compact forms.
  C.—Chlorite schists.

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[*] The Geology and Auriferous deposits of Southern Cross., Bull. 17, p. 18. Perth: By Authority, 1904.

[†] Geology and Mineral Resources of the Yilgarn Goldfield, Part I., by E. C. Saint Smith and R. A. Farquharson, p. 23, *et seq.* Perth: By Authority, 1913.

[‡] Geology and Mineral Resources of the Yilgarn Goldfield, Part I., by E. C. Saint Smith and R. A. Farquharson, pp. 68–69. Perth: By Authority, 1913.

Class II.—Rocks in which hornblende is the dominant ferromagnesian—felspar almost always present.
- A.—Without quartz, or with it only in small quantity.
  - 1.—Rocks massive or only slightly foliated.
    - (a) Epidiorites—platy and fibrous.
    - (b) Garnet amphibolites.
  - 2.—Rocks foliated.
    - Hornblende schist.
- B.—With quartz.
  - 1.—Rocks with hornblende in fibrous or other aggregates.
  - 2.—Rocks with compact hornblende and a granular or granulitic structure.
  - 3.—The contact-altered amphibolite.

In a further report, written in a private capacity for the Bullfinch Proprietary, and handed to the Department by the courtesy of the Directors of the Company, Gibson, in his reference to the greenstones of that particular area divides them into two classes, "the older greenstones" and the "newer greenstones."

The former he considers the oldest rocks of the district and describes them in detail as consisting of:—

> Fine-grained rocks which are invariably schistose, the intensity of the schistosity varying considerably. In some cases it is so slight that the rocks appear to be almost massive, whilst at times again it is so marked that they have the appearance almost of fine-grained fissile slates.
>
> Originally these rocks were probably fine-grained diabases, but they have now become, as the result of dynamic metamorphism, fine-grained schistose epidiorites.
>
> The "newer greenstones" represent the newest series of rocks in the field. Unlike the "older greenstones" they are essentially coarse-grained. They are occasionally found massive, the schistosity being usually very pronounced. The massive and incipiently schisted varieties represent merely "eyes" or lenses which have, to a certain extent, resisted the general shearing.
>
> These rocks were originally a coarse-grained pyroxenite, but are now, also as the result of dynamic metamorphism, uralite amphibolites and talc schists, the more massive portions being uralite amphibolites, while the highly schisted areas are talc schists, all gradations between the two being obtainable.

In correlating the evidence set out in the above reports, excepting Gibson's later one, and taking it in conjunction with data gained from a detailed survey of Southern Cross to Cheriton's section, the present author adopted a classification more or less corresponding with Gibson's, and the broader one of Farquharson's, viz.:—

1. The foliated variety merging into massive.
2. A coarse variety of hornblendites, the newer series of Saint Smith's, but probably a variation only of the first class.
3. Later unfoliated and massive.

Microscopic examinations of samples collected on the present survey tend to prove the existence of a variety of greenstones varying from hornblendites to epidiorites in every phase of alteration, but probably genetically connected, or in other words, derivatives of the same rock mass.

This does not necessarily presume they are of the same age, in fact, there is evidence against such being the case. But when it is evident that the main mass consists of bands or lenses of rock so intermingled as to be inseparable, and yet varying from one consisting almost entirely of one mineral hornblende to one in which felspar and hornblende are almost in equal proportions, there seems to be little doubt of their once being genetically connected, though subsequently by differentiation, now separated out as apparently different types. Presuming this to be the case, one would naturally expect to find the weathered products of such a rock mass, which had in the meantime been subjected to intense regional metamorphism, occurring in all the possible variations which could arise. A list of the prevailing varieties may be found in Saint Smith's report, above referred to. For the microscopic determinations of some of the rocks collected, *vide* appendices. For a fuller description of the field relationships, what has been written in Bulletin 63 stands for the Bullfinch belt.*

GRANITES.

The granites of the northern area of the Yilgarn belt form the eastern and western boundaries of the Bullfinch greenstones.

As a general rule, on the western side the contact is not visible, being for the most part overlain with sand. Where the rocks do outcrop, and they seldom do, is either in the "breakaways," in which case, as would be expected, the rock is seldom, if ever, not highly weathered,† or in the form of prominent knobs, good examples of which are Baladjie, Karolin, etc. The "knobs" are usually more or less unweathered. When thus seen the granite is found to be of a rather coarse-grained biotite microcline variety, in which occur frequent patches of very coarse aggregates of felspar and mica. The really unweathered portions are mottled black and white or grey. Coarse pegmatite dykes are of frequent occurrence.

Outcrops of granite on the eastern side are very rare. The contact with the greenstones has, however, been exposed in some of the mine workings, notably at Corinthian North and the Bullfinch mines. In each instance it is seen to be distinctly gneissic in character, the banding being fairly perfect. The bands consist of alternate layers of muscovite and biotite with quartz. The felspar is much decomposed and so cannot be identified with any degree of accuracy. How far this gneissic structure extends is not ascert able definitely, but it is of no great extent.

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* The Geology and Mineral Resources of the Yilgarn Goldfield, Part II. The Gold belt south of Southern Cross, by T. Blatchford. Perth: By Authority, 1915.

† Fig. 5.

Fig. 5.

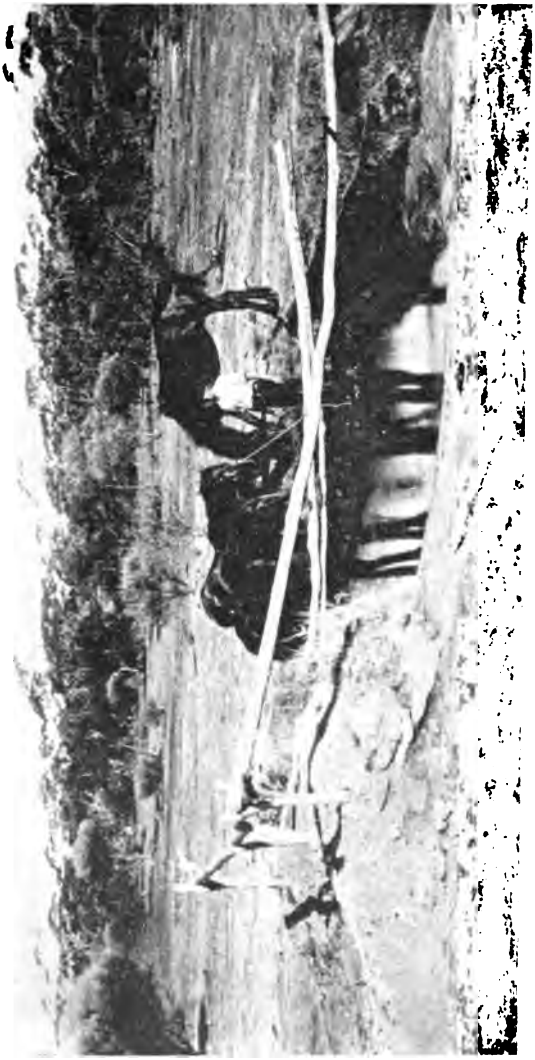

Photo: T. Blatchford.

A fresh sample of granite collected from the Government Tan at Ennuin was examined and revealed the following characteristic under the microscope:—

[$\frac{1}{710}$.] **This is a very coarse-grained grey granite rock with occa sional large semi-porphyritic scales, crystals and books of biotite. I** section there are very large platy and tabular crystals of partially kaolinised and partially micacised microcline felspar and less common plates of a plagioclase with albite twinning, with aggregations of irregular plates of quartz and occasional flakes of brown biotite, in places chloritic. Wedge-shaped crystals of sphene also occur, sometimes of considerable size. Some vermicular intergrowth appears in places, and an approach to zonary banding is noticeable in some of the felspar plates. Some of the most kaolinised felspars are quite turbid and enclose small grains of epidote. A few grains of black iron ore (ilmenite) appear sporadically. The rock is a very coarse-grained semi-porphyritic microcline biotite granite.*

Though far removed from this locality samples taken from Mount Gibbs, eight miles south of Hatter's Hill, and from near the 128-mile post on the Burracoppin-Starvation Boat Harbour section of the Rabbit-proof Fence, gave practically the same microscopic results. The latter are, therefore, cited for comparison in the appendices.

In summing up the microscopic evidence Farquharson states:—

> It is very evident that these three specimens, though collected from points many miles apart, all are so closely similar both in appearance, structure, and composition that they must be regarded as portions of the same, or a genetically similar mass.

It has generally been accepted by previous writers that the Southern Cross massive granite is of a later age and has intruded the greenstones. Saint Smith† has drawn a section showing the intrusive nature near Lake Polaris, but refers to such as "a tongue of granite of a fine-grained acidic type." Since both fine-grained aplites, as well as coarse pegmatites, are found invading the massive granite, this evidence as to the intrusive nature of the massive granite is not at all conclusive. However, apart from the evidence of the schisting of the greenstones near the granite contact, there is at least one definite and conclusive instance in the field where the granite in its massive form may be seen invading the greenstone belt.

This locality is situated some five miles south of Currajong, on the Southern Cross-Jackson road.‡

The granite occurs here, as the mapping shows, in the form of an extensive boss forming an inlier wholly surrounded by the greenstones.

This granite has the same characteristics as the massive granite and must be considered as a portion of the same mass.

It might be mentioned here that a similar occurrence illustrating the intrusive nature of the granite into the greenstones occurs too at Boodalin Soak, in the Westonia district. Furthermore, in this latter case, small areas of the greenstone are to be found in the granite mass as a further illustration of the intrusive nature of the granite.

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* Petrological determination, by R. A. Farquharson.

† Bulletin 49, G.S.W.A., p. 32. Perth: By Authority, 1913.

‡ Plates III. and VI.

There is, of course, no doubt as to the intrusive nature of the granite dykes, for such are repeatedly seen breaking through all the rock series, with the exception probably of a few later dolerite dykes.

As can be readily seen on the frontispiece and Plate I., the major portion of the field is occupied by granite. Unfortunately this vast area of rock does not contain lodes carrying either gold or the baser metals in commercial quantities. Certainly much of the surface is masked by recent superficial deposits of unknown depths. What lies under this cover is, for the present, uncertain. The prospects, however, of finding payable gold or mineral deposits is so remote that it is doubtful if they ever will be exploited, except perhaps in the vicinity of the greenstone contacts.

Referring to these superficial deposits, which are usually sandy or lateritic, one sometimes sees a small area of dark or red loam occurring as an isolated patch. It has been found that these patches are usually due to the disintegration of dolerite dykes, which represent probably the last stage of volcanic action. Further reference to these dykes will be made when dealing with the area at Mid Ironcap, where they are particularly frequent in occurrence.

QUARTZ-HAEMATITE SCHISTS.

This class of rock is well developed in the Bullfinch belt.* As a general rule it occurs in elongated lenses which run parallel to the eastern contact of the greenstones and granite, and usually at no great distance from the latter. On Plate VI., where the greenstones branch at Farren's Rock, this characteristic is very pronounced. The greatest developments of quartz-haematite schists occur in the Golden Valley district. Here parallel bands of the rock are seen practically right across the greenstone area. Quartz-haematite schists do not occur in the granite areas. At Corinthian they abut on the granite, which in this particular instance is distinctly gneissic, but do not intrude into the granite. The granite here merely forms the eastern wall for the deposit.

Throughout, the quartz-haematite schists exhibit a marked banded structure similar in every respect to those in the southern area of which they are an undoubted continuation. Their composition varies from massive haematite to a typical banded jasper rock. In addition to the foliation the rock is often found to be twisted and contorted and fractured to a marked degree. These contortions are sometimes found in only one section of the band, and this is no doubt due to lateral pressure combined with shearing in the rock mass before replacement by the iron and silica, and also to one portion of the rock being rigid enough to resist the shearing that has been induced in the weaker member. In several instances the lenses of quartz-haematite schists have been noticed to branch. Such is evident in the Violet, Bell Bird, and other mines, which makes it difficult to accept a sedimentary origin for the deposits which has been ascribed to them by some observers.

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* *Vide* Plates VI., VII., and VIII.

Opportunities have been forthcoming in some of the mine workings for observing the occurrence of the quartz-haematite schists at depths, and in such a marked change from the surface has been apparent. Thus in the Corinthian mine at the 200ft. level the haematite has been replaced largely by pyrrhotite, and in the Bullfinch mine at the 300ft. level both marcasite and pyrrhotite occur.

The structure of the rock also changes, the planes of foliation becoming less apparent in proportion to the depth. In general there is evidence of the quartz haematite schist gradually changing into the country rock. It should be noted, however, that both in the Bullfinch and Corinthian mines there has been a considerable amount of leaching and redistribution of mineral contents in both the encasing country rock and quartz haematite schists, and thus both these instances, where the subject can be best studied, may still prove to be exceptions to the general occurrence of the rock under review. There is undoubtedly a lack of definite information regarding the occurrence of these deposits at depth. So the conclusions arrived at can only be regarded as tentative.

As the occurrence is of importance from both a mining and geological standpoint, the following extracts have been taken from the writings of other observers both in the Yilgarn and other fields. Woodward, in his desciiption of the Nemesis mine states*:—

> The origin of one of these banded ferruginous quartzite bars is clearly demonstrated since the passage from the comparatively unaltered schist below the 250ft. level can be traced upwards through the pyritic quartz schists to its present oxidised form.

Farquharson's determination of a sample of rock taken from the bottom of this mine is as follows [12074]:—

> A heavy black rock with numerous fine bands of iron ore. Between the leaves in nearly all cases is a layer of rather large crystals of pyrites. Under the microscope the rock is seen to consist of quartz in polygonal plates with scattered grains and crystals of magnetite with small colourless plates of a green, slightly pleochroic hornblende. The latter bands are more densely charged with magnetite and contain frequently, besides, the ferro-magnesian shapeless patches of calcite. Round the border of the plates of hornblende, moreover, is a fringe of almost colourless needles of actinolite projecting at right angles to the rim into the surrounding quartz. A few large and small crystals of pyrites are to be observed. In several instances hornblende, that had almost completely lost its characteristic optical properties, is bordered by magnetite and closely associated with calcite which, indeed, is only to be found in the ferro-magnesian bands, and would, therefore, appear to be a decomposed product. Some brown iron staining is also to be seen in the green mineral.

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* Bulletin 48, p. 100, *et seq.*

Woodward's conclusions on the subject are definite, for he goes on to state:—

> It is apparent from the above that the rock composing these bars results from the alteration of ferro-magnesian minerals, and was of a similar character to the enclosing country.

In his report on the banded quartzites in the Murchison Goldfield,* at Lennonville, Mount Magnet, and Boogardie, Gibson divides the quartz schists into two classes—"the haematite" and the "non-haematite," the former being the more prevalent type, and in summing up the occurrences and origin he says:—

> The main bands of quartzites appear to have been old fault lines or joints, along which the original greenstones have been highly foliated parallel to the line of faulting or jointing, and thus form zones of weakness along which thermal solutions containing silica, iron, etc., have forced their way to the surface and gradually converted the original foliated greenstones into their present form. This appears to be borne out by the fact that they almost invariably run with the general strike of the country, viz., about north-north-west and south-south-east, and also that in several places they can be seen to tail out and invisibly pass into foliated greenstones.

In Maitland's description of the Mount Millicent quartzites in the Edjudina District,† he states:—

> All the available evidence seems to indicate that these lines or bands of quartzite have been found along shear planes, and that faulting took place subsequently to the deposition of the iron ores themselves.

and further on in a summary:—

> Analyses of the typical varieties of the different classes of ore showed that, contrary to their general appearance, they all contain a high percentage of silica and a relatively low percentage of iron. They are evidently not of clastic origin, occurring as they invariably do in the greenstone schists; these have invariably been subject to a great amount of bleaching and decomposition in close proximity to the deposits. The greenstone schists contain a certain proportion of iron compounds in their composition, and the bleaching action in proximity to the quartzites would seem to imply that these form the source of the iron ore and possibly that of the silica, with which these ores are invariably associated. The iron-bearing quartzites occur in the form of alternated overlapping lenses along what are evidently shear planes of remarkable persistence which, by virtue of the lamination, have formed channels for the more or less free circulation of mineral bearing solutions.

Gibson, in a report on the Murchison Goldfield, makes further reference to the banded quartzites of that district‡:—

> In no single instance have they been found in granite country.
>
> They (the quartzites) appear to be merely highly altered bands of foliated greenstone, and in some places can be seen to tail out imperceptibly into the latter. They are older than the quartz reefs. Their appearance at a depth is exactly similar to that at the surface, except in one case, where the hornblendite appears to be dying out and its place taken by blue quartz.

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* Bulletin 8, p. 16. Perth: By Authority, 1903.
† Bulletin 11, pages 28 and 58. Perth: By Authority, 1913.
‡ Bulletin 14, G.S.W.A., Perth: By Authority, 1904.

The same author, in writing about the haematite quartzites of Southern Cross, says:—

> These are similar to the haematite bearing quartzites of the Murchison and other parts of Western Australia, which have already been described in detail as "old faults or joint lines along which the greenstones have been highly foliated, and by a gradual lode forming process been converted into their present state."*

Jackson, in his description of the Mount Morgan's lode,† considers that:—

> Apart from its size and irregular nature it has many points of interest, not the least being its similarity of origin to the banded and haematite bearing quartz lodes which, though elsewhere frequently associated with auriferous deposits, are not themselves generally highly gold-bearing.

In a description of the Craiggiemore G.M., at Laverton,‡ he states that:—

> The ore bodies worked on this property are in every way similar to the haematite bearing quartzites. The whole country is very soft and rotten all through the present workings, and just begins to get hard and settled at the 300ft. level, at which point a fair amount of sulphide begins to make its appearance in the stone.

Saint-Smith,§ in describing the jasper bars or quartz haematite schists of Southern Cross, divides them into three classes in accordance with the percentage of silica present, with a possible fourth class "of subsidiary importance, which latter may represent the transition stage from normal greenstones to one or other of the three main classes of jasper." It is evident the author holds the prevailing idea that they are derived from the alteration or replacement of greenstones.

Farquharson, in dealing with the probable genesis of quartz haematite schists, is inclined to treat them as similar to the Lake Superior and Cuyuna deposits in America. It seems probable that his deductions were drawn from evidence derived from samples only of the bore cores of the Mount Caudan lode, which, without doubt, is of sedimentary origin ‖ and quite distinct in origin from typical examples of the class of rock under discussion. His petrological notes on the ore from the Nemesis mine read distinctly in favour of the general theory of replacement in crushed zones or fissures.

From the foregoing it would appear, therefore, that there is practically a consensus of opinion amongst observers as to the genesis of these deposits, viz., that they have been formed in the crushed zones of the foliated greenstones only, the main constituents, silica and iron, in the various forms of oxide, being derived, partly at least, from the basic rock.

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* Bulletin 17, G.S.W.A., Perth: By Authority, 1904.
† Bulletin 18, G.S.W.A., Perth: By Authority, 1905.
‡ Bulletin 24, G.S.W.A., Perth: By Authority, 1906.
§ *Bulletin* 49, G.S.W.A., Perth: By Authority, 1913.
‖ *Bulletin* 63, p. 65, *et seq.* Perth: By Authority, 1915.

It has been further noticed that where observed at depth in the mines there is a tendency for the gradual change or merging of the ferro-siliceous quartzite into the country rock. Furthermore, it has been observed in several instances that the iron oxides are replaced by pyrrhotite, marcasite, and pyrites in the deeper mine workings.

From an economic and mining point of view, considerable importance is attached to the occurrence of this class of rocks in the Yilgarn Goldfield.

Firstly because, in some instances, the quartz haematite schists have been themselves productive of highly payable gold ore.

Secondly, because gold-bearing quartz reefs are often found closely associated with them.

The best instance of payable ore being won from the lodes themselves is to be seen in the Bullfinch mine itself, a fuller description of which will be given under the heading of mines.

A glance at Plates VI., VII., and VIII. demonstrate that most of the mines and mine workings are at no great distance from the quartz haematite schist belts, which is evidence sufficient for the assumption that there is a close connection between them and the gold-bearing reefs and quartz leaders.

As a matter of fact, traces of gold can almost invariably be found in the quartz haematite lodes themselves, but, unfortunately, seldom in sufficient quantity to be of payable value. The Bullfinch mine is an exception, and the higher gold values found there are unmistakably due to severe faultings and subsequent local enrichments.

In the Violet mine, at Golden Valley, a pipe of ore of payable value has been opened out in a large haematite formation, but the gold values occur where an arm branches off the main body, and not in the main body itself.

At Ennuin gold has been won from the Marionette lease, but here again there has probably been local enrichment, due to the ironstone body being impregnated with auriferous quartz veins.

Of the associated quartz reefs, the best examples are the Corinthian and Corinthian North, Marie's Find, and several rich but small reefs at Eenuin.

QUARTZ REEFS.

Quartz reefs occur throughout both the greenstone and granite areas. In the latter rock they are usually of the massive type, non-auriferous, and probably of pegmatitic origin. Those found in the greenstone area may be classified under two headings, in accordance with their origin; but they likewise belong to two epochs when referred to their relative ages. As a general rule, quartz reefs have been found to be of a pre-pegmatite age, but in two instances there is undoubted evidence of the occurrence of a quartz vein after the granite dykes had intruded and cooled down, Further reference will be made to this exception in describing the Glideaway mine.

Another example is found in the same locality, where two quartz veins are being worked in a granitic dyke itself.

These, apparently, are exceptions, the general rule being that granite dykes intrude quartz reefs, thereby establishing the fact that they are of a later age. Of the hundreds of instances of this, the two instances mentioned above are the only exceptions which have been noticed. Classified according to their origin, the reefs in the greenstones come under two headings:—

(a) Ordinary quartz veins whose origin is undoubtedly connected with ordinary fissure-filling from circulating solutions.

(b) The pegmatitic type originating from fissure-filling by granitic ultra-acid residuum.

Veins of the first type are by far the most important, and the auriferous members of this class seem to be particularly associated with the quartz haematite lodes, or, in other words, they lie in or near the main fracture zone of the greenstones, and more particularly are they found where the granitic dykes are in evidence. Good examples of this are to be seen at Marie's Find, Manxman, Eenuin and Golden Valley. Everything tends to the one conclusion—that where the country rock has been fractured and undergone the most alteration there will be the most favourable areas for mineral deposition and concentration. My frequent reply to the prospector who is often found speaking disparagingly of the granite "bars" is, "Where you do not find those, you won't find gold; so you must take the two together or none at all." Of all the payable mines in the Southern Cross belt, the writer knows of three only in which granitic dykes do not occur; and two of these, the Victoria and Broncho, are in a class of their own, and unlike any others in the above goldfield, whilst the other is the Bullfinch Proprietary, another more or less exceptional case.

The second class, probably derived from the granite magma direct, is not very pronounced, but is represented in one or two instances by conspicuous outcrops. They are usually known by the prospectors as "Buck" reefs. There is no instance on record in the Bullfinch belt in which they have proved of any value as gold bearers.

Quartz reefs in the Bullfinch belt proper do not play the same important part as they do in the southern area, whether viewed from a geological or mining aspect. As a matter of fact, their occurrence, as a whole, is not only less frequent but the auriferous ores may be said to be comparatively scarce.

However, there is always a likelihood of discovering fresh auriferous quartz veins in the vicinity of or connected with the quartz haematite schists, though away from such the chances of single instance on record where this has led to a successful issue.

This limits the range for prospecting considerably, and really reduces the probable auriferous area to very narrow limits.

Unfortunate as this may be from a mining standpoint, it is nevertheless a fact, though, of course, exceptions may arise in the future, in spite of this rule having held good up to the present date for the Bullfinch, Southern Cross, and Marvel Loch belt.

GRANITIC DYKES.

Throughout the greenstone and granite rocks are numerous more or less narrow dykes of undoubted granitic origin. In the greenstone areas they are extremely common on the eastern contact. To illustrate their frequency, a small area at Marie's Find was taken as an example and each of the dykes mapped.* This illustrates the occurrence, but it will be seen that to have continued mapping on this scale throughout the whole field would have taken far longer than was warranted. For after all, except that the acid dykes occur with persistent frequency in the areas where gold-bearing reefs are found, they have little bearing on the auriferous nature of the quartz vein itself; the chief significance of their association is that both the occurrence of the reefs and dykes point to the fact that the areas in which they are found have probably been suitable for not only circulating solutions, but also the admission of the narrow dykes. In other words, where dykes can invade, there the conditions are suitable also for circulating solutions, and there is a probability of the introduction of minerals from such solutions. The sizes and field relations of the most conspicuous of these dykes can be seen on Plates VI., VII., and VIII.

The granite dykes invade all classes of rock, with the exception of the dolerites, and though they may be of later age even than these they have not been observed passing through them.

In the Glideaway mine an instance of their being of two ages is evident, for the Glideaway reef passes through a series of acid dykes in one part of the mine, whilst in another a rather large granite dyke cuts through the reef.

As far as observed no instance occurred in which base minerals were found in acid dykes. Reference has already been made to gold occurring in two small veins occurring in a granite dyke. This is the one exception in which gold has been directly associated with this class of rock and is almost negligible.

SUPERFICIAL DEPOSITS.

For the most part the surface of the country is covered with superficial deposits. These deposits vary in composition relatively to the underlying rock. Thus, on the granite areas we find siliceous laterites and sand to sandy loam, whilst on the greenstone areas one finds isolated patches of ferruginous laterites and loam.

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* Vide Plate VI.

The deposits in the dry lake areas have already been referred to.

Practically little is known about the depth or extent of these surface deposits, as there has been no inducement to exploit them. There is no record of any alluvial "leads" being discovered. As a matter of fact, alluvial gold has been conspicuous by its absence throughout the belt.

Taken as a whole the surface deposits form a mantle, covering most of the area under review, about which practically nothing is known.

IX.—GEOLOGY OF THE WESTONIA CENTRE.

The Westonia belt is situated some six miles north of Carrabin, a railway station on the Eastern Goldfields line, 195 miles distant from Perth and about 40 miles west of Southern Cross.

EXTENT OF THE BELT.

Compared with the other four greenstone belts, that of Westonia is the smallest.

Its total length is some 23 miles, with a maximum width of not more than five miles. The shape is irregular, the central portion being a very narrow neck connecting the northern and southern ends, both of which have much greater dimensions.

The southern extremity gradually merges into flat, sand-covered country, presumably granite, but the boundaries here are most indefinite.

The same conditions prevail on the northern end, but the country being of a greater altitude there, makes the boundary somewhat more definite.*

HISTORY.

The first official notice of the discovery of gold in the Westonia district was the application for a reward claim near Boodalin Soak by A. D. Weston on 20th December, 1910. This lease is now known as Weston's Reward, named after the discoverer, as also is the township Westonia.

Further applications for gold leases soon followed Weston's application, thus we have one by J. Cooke on 30th December of the same year for the Recovery G.M.L. 2097; by E. J. Annear for the Edna May G.M.L. 2180 on 10th January, 1911; by C. Hickey and Asphand for Myrtle Consols G.M.L. 2168, 9th January, 1911; by

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* *Vide Frontispiece.*

Tom Dunn, Myrtle Consols South G.M.L. 2238, 23rd January, 1911 (these two leases now comprise the Edna May "Deeps" mine); by A. F. Hanks, Myrtle Central G.M.L. 2291, 10th February, 1911 (now the Edna May Central mine); by J. V. Kearney, the M.A.W. lease 2409, afterwards applied for on 5th June as the Myrtle East by R. Holmes, and now part of the Consolidated Gold Mine; and G.M.L. 2617 by Squires and others in March, 1911, afterwards applied for by De Jersoe in 1912, also part of the Consolidated group.

For some considerable time only one of these leases—The Recovery—yielded gold in appreciable quantities, and, in its early stages of development, gave promise of being a high-grade mine. As a matter of fact, it seems quite probable that the first crushings from the Recovery were the means of keeping prospecting alive in the early stages of the field. Certainly it was trying to locate the continuation of the Recovery reef which led to several, if not all, of the above leases being taken up as mining holdings. It is generally understood amongst some of the original prospectors that after the Recovery, gold was next "struck" east of the Recovery in the "water" shaft on G.M.L. 2761 (Edna May Consols), and that the latter find lent colour to the prevailing idea that the Recovery reef extended in that direction. Certainly it was the means of further prospecting between the water shaft and the Recovery, and, therefore, the indirect cause of finding the main Edna May-Central lode, a discovery sufficiently important to lay the foundation of a mining centre of considerable importance. Unfortunately, the Recovery reef proved disappointing, and had it not been for the discovery and proving of the Edna May line probably there would have been a general exodus of the prospector. As it happened, the first crushings from the then Myrtle Central and shortly afterwards the Edna May were such as to give every encouragement to further prospecting. To illustrate the advancement in mining after this period one has only to note the development in mining plants. Up to the end of 1912 there was but one small reduction plant on the Recovery lease. In 1913 the Edna May Company erected a ten-stamp mill, followed by the Central in 1915 and in 1916 by the "Deeps" and "Battler," with mills of a similar number of stamps.

In addition, several mines, chiefly the Edna May, expended considerable amounts of money in pumping and winding plants, air compressors, etc. Up to the present time the Edna May is the only plant equipped with a cyanide plant for treating both sands and slimes. Unfortunately, prospecting during the years 1914 and 1915, apart from the Edna May Central mine, met with little success. Certainly, several small veins carrying high-grade stone were found, but these were unimportant in [illegible] true mining sense. The chief mining venture of 1915 was really the attempt to intercept the Edna May line at depth, and with this object in view the owners of the

Myrtle Consols and Myrtle Consols South floated a company, known as the Edna May "Deeps," to raise sufficient capital to attain this objective, which resolved itself into sinking a vertical shaft from 500 to 600 feet in depth.

It was whilst sinking this shaft that heavy water difficulties were met with and overcome by a cementing process, which is well worthy of notice and redounds to the credit of N. Stuckey, the manager in charge.

In brief, the *modus operandi* adopted was as follows:—A trial hole was always bored well ahead in the bottom of the shaft. When heavy water was struck a force pump was connected to the bore hole by a suitable wooden plug fitted with a pipe valve and hose, and liquid cement was then pumped into the hole until the pressure rose to the limit of the pump (from 300 to 500 lbs. to square inch). The hose was then disconnected after the valve had been closed; when several holes had been treated in this way, in the bottom and sides of the shaft it was found that, due time for the setting of the cement, of course, having been given, the water was held back and the bottom of the shaft could be fired out as usual and be practically free from water, thus demonstrating that small open fissures forming water channels could be definitely cemented up and permanently sealed, at least in unweathered rock. The process is new to mining operations in this State and, in the writer's opinion, should be of use where the conditions are similar to those which arose in the "Deeps" mine. The Edna May reef was eventually struck in a drive from this shaft at the 480 feet level. The result was an important one in that it proved not only the existence of the main reef at this depth, but also that the gold values likewise continued.

GEOLOGY.

The rocks of the Westonia Boodalin belt resolve themselves into the following groups, which are placed in relative chronological order commencing with the oldest:—

Sedimentary metamorphics.—Non-auriferous.
Basic Rocks (greenstones), plutonic.—Auriferous.
Gneiss—Edna May Gneiss, intrusive.—Auriferous.
Granites, massive plutonic.—Non-auriferous.
Ultra Acid pegmatites (lodes).—Auriferous.
Basic (greenstone dykes).—Non-auriferous.
Quartz reefs.—Auriferous.
Granitic intrusive pegmatites, aplites.—Non-auriferous.
Recent superficial deposits.—Rarely auriferous.

Probably the oldest rocks of the field are the sedimentary series found near Boodalin railway siding. There is a very marked resemblance between these sediments and those of Parker's Range, Marvel Loch,* Bullfinch and Eenuin, so marked, in fact, that it is only reasonable to suggest that they formed at one time a continuous series, lying horizontally on a fundamental gneissic floor. Subsequent earth movements buckled these beds into folds with axes striking north-west south-east; at the same time basic rocks were intruded. Later on these basic rocks, in turn, were intruded by magma of an acid character, which latter resulted in the formation of the gneissic belt, called in the following pages the Edna May gneiss.

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* Bull. 63, G.S.W.A., p. 29. Perth: By Authority, 1917.

Following these early earth movements comes the intrusion by the Southern Cross granite, the result of which was not only the taking up of the major portion of the area with one prevailing type of granite, but also the introduction of different characteristics to the whole of the then existing rocks both in the rearrangement of their minerals and the introduction of different physical features.

Hence we find the coarser sediments crushed and foliated with extensive developments of fresh minerals such as andalusite, garnets, etc., in the finer varieties.

In the basic rocks hornblendes have changed largely to mica, etc., and both the basic rocks and Edna May gneiss have been highly foliated. On the cooling and consequent contracting of this complex, extensive faulting took place, followed by injections of both an acid and basic character.

Apparently the first of these injections were acid and resulted in the formation of the ultra acid dykes now worked as highly profitable gold-bearing lodes.

These were followed by basic intrusions which passed through the former and were afterwards subjected to the same treatment, for we find further acid intrusions which passed through one and all the members of the plutonic and volcanic series. The injection of these acid dykes is the last evidence of volcanic action in the district. Though there must needs have been extensive faulting in the rock complex there has apparently been little other movement as, with one exception, there is no evidence of throw in any of the faults.

SEDIMENTS (METAMORPHIC).

The sedimentary series in the Westonia section is but poorly represented, and is only found outcropping in one locality, viz., north of the railway line at Boodalin.

A group of leases known as the Comstock embrace most of this area.

On the surface the rocks have weathered considerably, the result being a mixed ferruginous coating resembling the prevailing ferruginous laterite deposits in appearance. In one instance only was there any semblance of this ironstone being the capping of a lode such as found in the corresponding sedimentary areas of Marvel Loch or Parker's Range.*

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* Bull. 63, G.S.W.A., p. 64. Perth: By Authority.

It would appear from the shallow workings that gold has been found by prospectors, but not in sufficient quantity to warrant any extensive development.

Where the original rock could be seen, samples were taken and such have been examined by the Petrologist, with the following results:—

G.M.L. 1117:

[$\frac{1}{2}$]. This is a very fine-grained dirty greyish-black somewhat porous graphitic rock, the numerous minute white scales or rods all arranged with the long axes parallel. There is a suggestion of shearing in the specimen, and the specific gravity is light. Owing to the denseness of grain, the rather soft nature of the specimen and the graphitic content, it is very difficult to obtain a section of the rock of any value. It is possible, however, to make out that the body of the rock is composed of small quartz grains heavily charged with a black dust, of which some particles have the appearance in reflected light of graphite scales. Doubtless there is a considerable amount of amorphous graphite as well. In addition to these constituents there are occasional pale yellow fibrous flakes, resembling decomposed mica and, rarely, rather large areas of minute scales of mica heavily charged with the black dust. These large micaceous aggregates are of obscure origin, but are consistent with a derivation from original chiastolite. From the character of the rock and from comparison with undoubted chiastolite shales from the same field, it is probably a sheared, much altered, graphitic shale of the chiastolite-shale series.

[$\frac{2}{2}$]. An extremely decomposed rock, apparently sheared or indistinctly laminated, somewhat porous, extremely ferruginous, and of a brick-red colour, with numerous pale slate-blue rounded forms that are soft and granular, and in places blackish. The rock is too much altered for sectioning, but appears to be slightly graphitic. The bluish forms were at first sight thought to be flinty, but their soft nature indicates that they are probably decomposition products. Tests, however, with the blow-pipe failed to reveal a strongly aluminous character, but this may have been due to the presence of carbon, and it is probable they are decomposition products of andalusite.

The rock is of doubtful origin, but it is classed as a weather ferruginous clayey product of an *andalusite shale.*

In both instances the rocks have proved to be closely allied to shales much altered and impregnated with graphite, a frequent characteristic of the sediments in the Bullfinch belt. Careful investigation of these beds is impossible owing to the paucity of outcrops and mine workings. They are unimportant from a mining point of view, for, as a general rule, throughout the Yilgarn goldfield they have been proved to be non-auriferous except in rare instances, along their contact with the greenstones.*

GREENSTONES (plutonic).

Next in importance to the Edna May gneiss, especially from an economic or mining point of view, are the greenstones.

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* For further reference to Occurrences of Sedimentary Rocks, *vide* Bull. 63, G.S.W.A., p. 20, *et seq.* Perth: by Authority, 1915.

As previously mentioned, the greenstones form a more or less narrow belt, extending through Boodalin railway siding, north-west past Weston's and Boodalin soak. In the centre of this belt is a pronounced necking.*

Under existing conditions it is an impossibility to map the boundaries accurately, as the contacts are almost invariably covered with surface detritus. The boundaries, therfore, as shown on Plate IX. and frontispiece, must be considered as approximate only. Furthermore, this prevailing overburden has so seriously interfered with the possibility of mapping the various rock types, that detailed work in this direction was almost futile.

However, wherever outcrops or mine workings were available, samples were taken and examined, and by this means sufficient information was obtained to admit of a general classification of the rock matrix being made. Several bore cores, too, were carefully sampled, and these were found extremely useful in the investigations.

In an interim report on the Westonia district by the present writer in the year 1914, the greenstones were subdivided into three main groups (1) Diorites; (2) Amphibolites, and (3) Peridotites.

The diorites were further subdivided into four types, the classification being made with reference to structure and composition.

A. Normal diorites.—A rock in which the hornblende and plagioclase (felspar) are in approximately equal proportions.

B. Fine-grained felspathic diorites, in which the felspar predominates.

C. Fine-grained hornblendic diorites, in which the hornblende predominates.

D. A distinctly gneissic variety.

The last of these it was found possible to isolate within moderately definite boundaries.

The above classification was only a tentative one and drawn up from hand specimens and a few rock sections cut in the field.

Since the issuing of the above report, a considerable amount of detailed work has been done by Farquharson† on specimens collected from the surface, mine workings, and bore cores. Whilst recognising numerous facies, in that writer's opinion the whole of the greenstone types may be resolved into two main groups. The following is a list of the types, with a brief summary of their relationships as written by the observer†:—

1. A foliated hornblende gneiss occurring in a thin lenticular mass from the Junction lease to the western boundary of the Elsie lease. The rock is in places quite coarse-grained and dioritic in appear-

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* Frontispiece.

† R. A. Farquharson, Petrologist, G.S.W.A.

ance, in places quite fine-grained, while in some rock specimens felspar is equally developed with the hornblende; in others, hornblende is much in excess of the felspar.

2. The granulitic hornblende schist. This occurs in the Elsie lease in shafts south of the point at which the hornblende gneiss disappears.* It occurs at the south-west corner of G.M.L. 2079; it is found in shafts at the eastern margin of the Myrtle lease, and is predominant in Nos. 2 and 3 bores, Edna May mine.*

Further, both the hornblendic gneiss and the granulitic hornblende schist occur in a shaft at the south-west corner of G.M.L. 2762, though specimens of the former are much decomposed.

Finally, a foliated fine-grained hornblende gneiss or granular quartz amphibolite, and a fine-grained prismatic hornblende schist occur in the Lloyd George mine.*

3. A foliated pyroxene-hornblende-felspar rock occurring at the old townsite.*

4. A foliated hornblende-schist or epidiorite at Bodallin soak. This is virtually identical with the granulitic hornblende schist.*

5. An acicular hornblende schist verging on a granulitic hornblende gneiss, and a fine-grained foliated prismatic or roddy hornblende schist with lenticles of pyroxene, found in the Battler lease.

6. A foliated amphibolite or diorite occurring near the bottom of Duff's bore at about 785ft.,† and a coarse platy diorite at 438ft. in the bore at Weston's Reward.

7. An actinolitic chloritic hornblendite, occurring at the plat in the Edna May shaft 300ft. level, and at a depth of 427ft. in Duff's bore.†

8. Finally, a tremolitic serpentinous rock found at 466ft. and greater depths in Duff's bore, also the plat in the Edna May shaft, and, judging from weathered clayey specimens, in shafts near the western margin of G.M.L. 2617.

These facies are ultimately reducible to two groups:—

(a.) Foliated felspar-hornblende rocks. These include rocks with quartz such as the foliated hornblende gneisses or quartz diorites, and those without quartz or with it in such small amount, such as the granulitic hornblende schists and foliated epidiorite and the foliated pyroxene hornblende schist.

(b.) The non-felspathic hornblendic rocks. Included amongst these are the actinolitic chlorite hornblendite and the tremolitic serpentinous facies.

The mutual relations of the rocks:—

Owing to the impracticability of observing rock junctions, to the paucity and scattered nature of the exposures, most of which are confined to shafts or to the mine workings, and to the absence of any decisive field evidence, the mutual relations of the rocks are very difficult to make out.

The chief facies are undoubtedly the granulitic hornblende schist and the hornblende gneiss, and of these the former certainly appears to have the wider distribution, and is probably the chief member of the country rock.

In this connection, the inliers of greenstone at Boodalin soak must, from their occurrence, be regarded as representative of the country rock, and these, as has been shown, are foliated hornblende schists or epidiorites closely resembling in structure and composition the horn-the foliated pyroxene hornblende felspar rock of the old townsite, though apparently different from the hornblende schists, has been shown to consist of hornblende portions microscopically very similar to the latter, and since it is plain in the slides that the hornblendic portions have been derived from the pyroxenic, there is little doubt that the hornblende schists have been derived ultimately from a rock similar to this and from the old townsite, and that this pyroxene rock must be included, from the point of view of origin and affinities, with the hornblende schists.

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* Plate IX.

† Edna May "Deeps."

The relationship of the hornblende gneiss, however, to these hornblende schists is by no means clear. It apparently occurs mostly as a band or strip more or less surrounded by hornblende schists, and since some varieties of it differ only from the presence of a little quartz, while exhibiting the same appearance and structure, it might be regarded as a derivative of a more quartzose modification of the original of the schists. On the other hand, from the characters of [13996], and of the bore core from about 785ft. in Duff's bore, it certainly appears to have been formerly a quartz diorite, and as such may have been a more acid dioritic intrusion into the original pyroxene-felspar rock that subsequently gave rise to the hornblende schists.

Though both the hornblende gneiss and the hornblende schist occur in a shaft at the south-west corner of G.M.L. 2763 and also in the Lloyd George lease, no evidence is obtainable of their mutual relation, and the evidence afforded by the bore cores is inconclusive. For the present, therefore, their relation must remain doubtful.

In the case of the actinolitic hornblendite and the tremolitic serpentinous facies, there is even less evidence of the relation of one to the other or either to the surrounding rocks. All that is known of the hornblendite is that it occurs in two places:—

(a.) Duff's bore at 427ft. At that point there is a clean break between it and the granitic gneiss that extends off and on from the 180ft., and at about 466ft. it passes into the tremolite serpentinous rock.

(b.) In the plats in the shaft at 225ft. and 300ft. level, Edna May mine.

In these localities it occurs again in association with the tremolitic serpentinous rock, but again the relation of the two rocks to each other and to the granitic gneiss is obscure. Subsequent investigations afford evidence suggesting that the hornblendite and the tremolitic serpentinous rock are but facies of one ultra-basic type.

Whether they are ultra-basic dykes and only magmatic modifications one of the other, whether they are separate dykes of different age, or whether the hornblendite at least is a basic modification of the hornblende schist—these questions owing to the lack of exposures and evidence generally—cannot but remain unsettled.

The major portion of the greenstone complex may, therefore, be considered in broad terms as one consisting essentially of hornblende and felspar in varying proportions, the hornblende predominating at times [illegible] the almost total absence of felspar. Frequently the hornblende is found almost completely changed to biotite, the intermediate stage chlorite being relatively of common occurrence. Quartz, in small quantities, is frequent whilst

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* Plate IX.

sphene is not at all an uncommon accessory. Taken as a whole, the rock mass is foliated. It is highly probable that this foliation is due to the invasion of the main granite mass, which completely surrounds the greenstone belt. The foliation planes are not always visible to the naked eye in the finer-grained forms, but in the weathered, coarse-grained rocks they are readily discernible. Under the microscope in thin sections, however, and without exception, the rocks are seen to be foliated. The planes of foliation run approximately parallel with the granite contact.

In the mapping, one section of the greenstones has been separated from the remainder. This consists of a narrow belt of a rather conspicuous white mottled rock, which strikes northwest through the Recovery, Myrtle, and Advance leases.

Petrographically, this rock does not differ to any great degree from the main mass and might easily be placed as a variation of the latter. However, in the field its general appearance is so marked in comparison to the immediately surrounding rocks that one is inclined to the alternative that it is a probable intrusion. The attenuated shape lends weight to this decision.

Furthermore, there are characteristics from a mining point of view, which also add weight to this decision, for it is found that several small quartz veins worked in this coarser-grained rock do not, apparently, pass into the finer-grained encasing rocks; such quartz leaders have been proved to contain gold in payable quantities, though the reverse applies to veins immediately outside this belt. Otherwise, there is no strong field evidence to support the differentiation of this small lens-shaped belt from the main mass.

In the Edna May shaft, and in ''Duff's'' bore, a band of rock classified as a hornblendite, has been pierced, which is distinctly more basic in character than the main mass. Unfortunately, this band does not outcrop at the surface and has not been intersected in the mine workings elsewhere. Its origin is, therefore, obscure. However, if the theory be accepted that the main greenstone belt was invaded and foliated by the massive granite and that this took place after the greenstones were invaded by the Edna May gneiss, it follows that the basic rock in question is, in all probability, an intrusive into the main greenstones. For in the Edna May gneiss are found basic dykes, so closely allied to this hornblendite, both in lithological and petrographical characteristics, that it would be difficult to conceive that they were not genetically connected, and, therefore, necessarily of a later age than the main greenstones and Edna May gneiss. They are, likewise, probably of a more recent age than the main granite as their planes of foliation are not parallel to those of the Edna May gneiss.

Further reference will be made to the basic dykes later on in this report.

EDNA MAY GNEISS.

The belt of rock referred to in the pages of this report as the Edna May gneiss is the most important and interesting of the rock species in the district. Important, because in it occur the principal gold-bearing lodes, and interesting because it represents a class of rock not commonly found in the Westralian goldfields.

The rock does not outcrop at the surface, but is persistently covered with an overburden of recent deposits, varying in thickness from eight to certainly 75 feet, probably more. However, the boundaries of the belt have been defined with a fair degree of accuracy in the various mine workings. On account of the overburden, these boundaries have been plotted on Plate IX., at a depth of 73 feet in preference to projecting them to the present surface level.

This plotting shows that the rock occurs as an elongated lens passing at a depth of 73 feet through leases 2168, 2238, 2180, 2291, and 2570, and terminating, apparently, in the eastern end in lease 2167, and in the western in lease 2088.

The maximum width of the lens is 410 feet, the greatest developments being in leases 2180, 2291, and 2570. To a vertical depth of 400 feet, the footwall of the lens has a persistent dip to the north of an average angle of 58 degrees. The lens will, therefore dip into leases 2168, 2585, 2615, and 2644 at a comparatively shallow depth. Unfortunately, there is no evidence available as to the dip of the hanging wall or northern side; the only two places where this wall can be seen are at the 73-feet level in the Edna May Central mine north crosscut, and at a depth of 46 feet in No. 5 shaft in "Deeps" G.M.L. 2238. The dip of the hanging wall is, therefore, not known, but it is certainly towards the north.

As far as can be ascertained, the encasing rock of this lens is hornblendite. As has already been stated, this hornblendite is probably a later rock than the foliated felspar hornblende rock which is the prevailing type of the district; any relationship which may exist between the lens and this latter rock series is, therefore, masked. The lens of gneiss consists of a foliated quartz mica hornblende rock, which on petrological and chemical examination has proved to be intermediate between a quartz diorite or granodiorite and a basic granite. Farquharson, though inclined to the granodiorite classification, writes with an open mind on the subject and states that the rock may be one of three classes:—(a) [illegible] ential product of the foliated hornblende gneiss (the prevailing greenstone of the district); (b) a granodiorite; and (c) a foliated basic hornblende granite.

In the upper mine workings, where the rock is seen in its weathered condition, the planes of foliation are still clearly marked. The felspars, as a rule, have been completely kaolinised; mica still exists, but more in the secondary form of sericite. When broken in the hand, the rock is distinctly gritty and is thus easily distinguishable from the weathered products of the basic rocks. In colour, the decomposed rock varies from a grey to a reddish-brown, but at times is almost white. This latter form is due probably to the excess and total weathering and bleaching of the felspar. In the undecomposed zone the planes of foliation are very evident, and the general structure of the rock is gneissic.

The strike of the planes of foliation is, approximately, east and west with a general variation of usually not more than 10 degrees from this bearing, with exceptional cases only of a greater angle.

As a general rule, the oxidised zone reaches a vertical depth of about 130 feet, or some considerable depth below the present water level, which stands at about 75 feet. Portions of the rock, however, are weathered to a depth of 200-250 feet, but this is only along the contacts and not in the main mass. On the south side of the lens a small band of the gneiss is found passing through the greenstones, which probably represents an arm of the main mass. It certainly has the same lithological characteristics. Throughout the gneiss occur dykes of basic rock, pegmatites, and, later, aplites; also innumerable quartz veinlets which are, at least in numerous instances, probably segregation veins.

The nature of these intrusions has already been dealt with under their various headings.

Returning to the question of origin, there are certain points which arise from observations in the field which may be taken with or treated separately from the microscopic evidence, but still have an importance which must not be neglected. For instance, in the Edna May gneiss certain pegmatites occur which are undoubtedly closely associated to the containing rock. Furthermore, as any known granite mass has always accompanying apophyses, it is only natural when granite apophyses are found to look for the parent granite. In the present case it would be most unlikely that the origin of the pegmatites in the gneiss could be traced to the outside granite. There seems no possibility of this being the case. If the gneiss be accepted as a differentiated portion of a granite magma, in which hornblende, though present, be considered as an accessory mineral, the subject of origin could be easily cleared up; otherwise, from whence do the pegmatites arise and whence the gneiss? In certain phases the difference between a granodiorite and basic granite is so small that the nomenclature is merely a matter of opinion. The chemical analysis of the Edna May gneiss is certainly, as Farquharson points out, very similar to that of certain recognised granodiorites. It must be recognised, however, that in a much altered rock mass, as the gneiss apparently is, the original rock may have undergone considerable chemical change, sufficient to turn the balance either way. Taking the evidence as it stands, it seems more than probable, and certainly more satisfactory, to couple the gneiss and auriferous pegmatites as one pair and the granites and aplites as another, with distinct ages, though, possibly, genetically connected. The occurrence of gold-bearing lodes in an acid rock is not unique in Western Australian mining, as commonly believed and reported. For example, the principal mines of the Cue district are in a granodiorite, the Cosmopolitan mine at Kookynie in granite, and the principal mines of Quinn's in a granodiorite.

Two other instances of acid gneisses occur in the district, one in the Battler gold mine, the other in the Hill End gold mine, in the same vicinity. There is a striking similarity between these two rocks and in some respects they resemble the Edna May gneiss, though in composition and structure there are various differences between the two classes. Farquharson is inclined to the idea that they are representatives of different magmas, but implies the possibility of their being apophyses of the intrusion, which gave rise to the Edna May rock. Certainly, they are intrusive into the greenstones, and are seen in the field occurring as narrow dykes. Unfortunately, except where opened out in the mines, they are not visible, except as decomposed fragments on the surface. However, their importance is evident in that they contain lodes which, though small, are distinctly auriferous, and for this reason attention should be drawn to their occurrence in case similar occurrences are found in the ordinary course of prospecting. A full description of the nature and composition of these rocks, also of samples taken from the Edna May gneiss, are to be seen in the appendices.

GRANITES (massive plutonic).

The granites of Westonia bear so strong a resemblance to those of the Southern Cross-Bullfinch area, that they must be classified as probably the same rock mass.

Setting apart the numerous acid aplites and pegmatitic dykes, they can be classed under two headings:—

1. Massive varieties.
2. Extensive tongues and bosses, portions of the massive portion.

Outcrops of the first class are rare, with the exception of the granite knobs found in the country lying between the Rabbit Proof Fence and Bullfinch.

In the vicinity of Westonia there are three outcrops, one at Boodalin soak, one at Yorkrakine, and the other near the magazine at Westonia.

In the first are numerous examples of the greenstones having been caught up in the granite mass, as can be seen on Plate IX. The granite here is a biotite microcline variety, similar in every respect to the Southern Cross varieties.

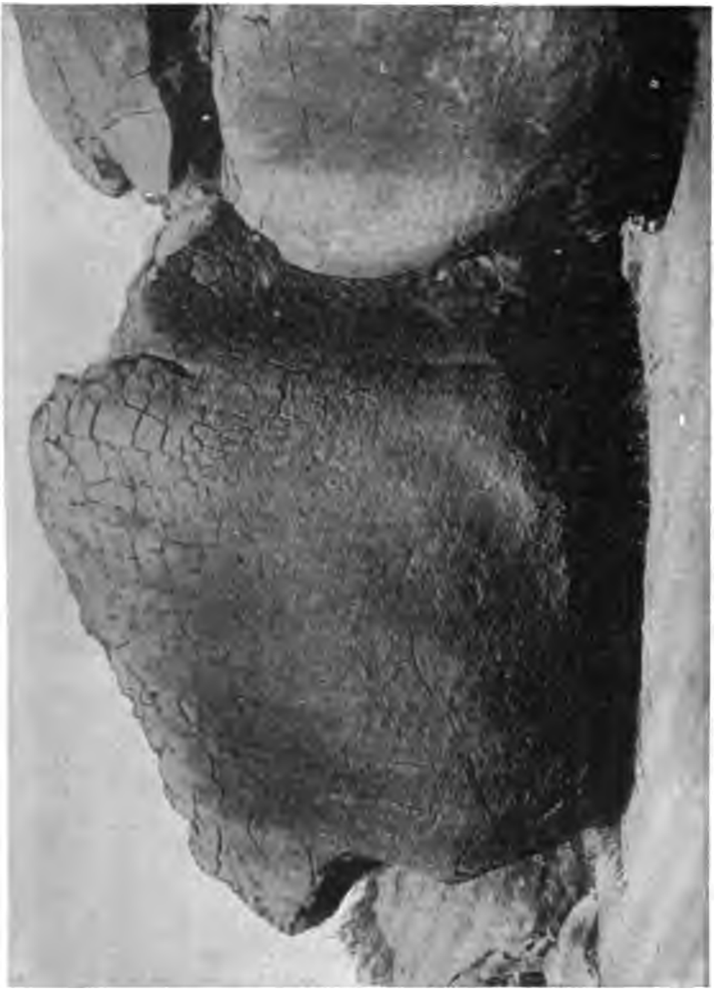


Fig. 6.

Photo: T. Blatchford. Neg. 1314.

Granite "Tor," Boodalin Soak, showing surface weathering.

Some of the "Tors" show a marked weathering, which is illustrated in Fig. 6. Otherwise there is nothing of significance to note about the occurrence.

The Yorkrakine rocks stand out as prominent landm and afford a good opportunity for the observance of sev characteristics of the granite of the area.

Fig. 7.

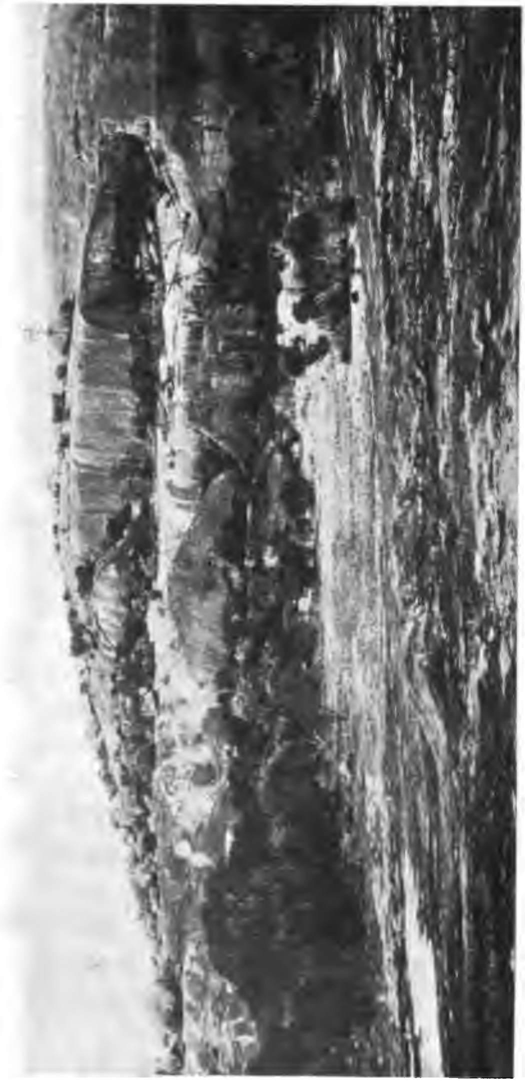
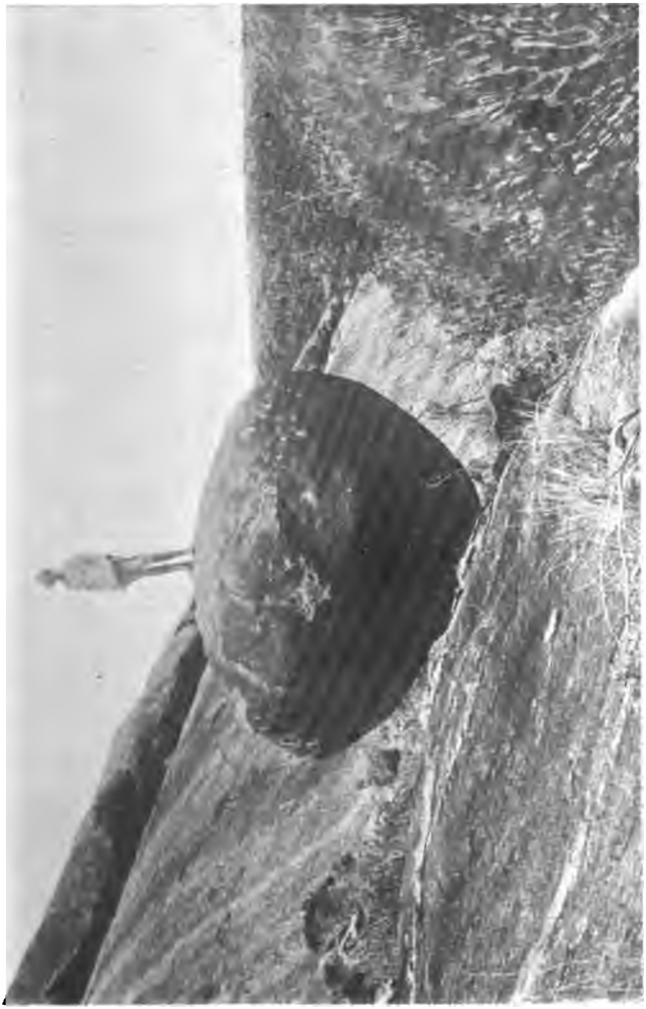


Photo: T. Blatchford. Yorkrakine granite—illustrating surface scaling Neg. 1310.

One of the most noticeable features to be observed is weathering.

Huge flakes of the rock are seen cracked from the main mass on curved faces, and, in many cases, have slipped and fallen from the tops to the base; Figures 7, 8, 9, 10, illustrate this better than a written description.

Fig. 7.



Detached granite boulder, Yorkrakine rocks.

Photo: T. Blatchford. Neg. 1311.

Throughout the mass patches of felspar and mica aggregates occur, which are disconnected and apparently segregations only. In one instance in particular, a coarse-grained pegmatite dyke is seen cutting through the mass in almost a mathematically

straight line. In two places this dyke is faulted (*vide* Fig.
Basic patches, probably representing caught up fragments of

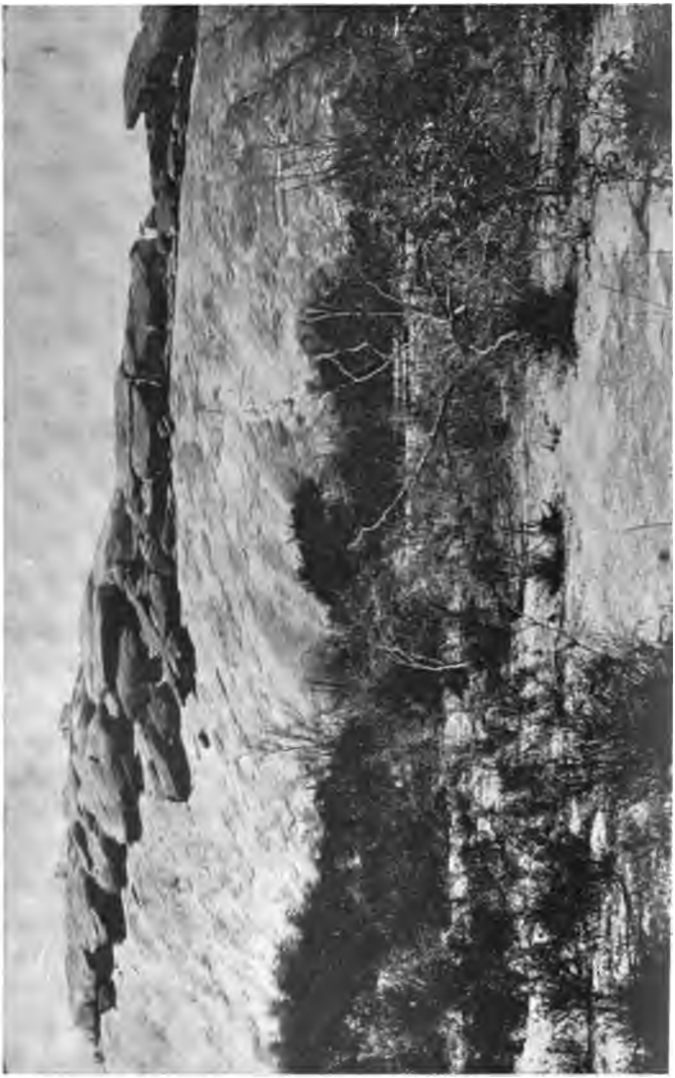


Fig. 9.

greenstones are not uncommon. The granite is of the biot
microcline variety, the minerals being fairly uniformly dist
buted. In texture there is considerable variation, the felspars
places almost giving the rock a porphyritic appearance, otherw

the rock may be classed as a typical, fairly coarse-grained grey granite.

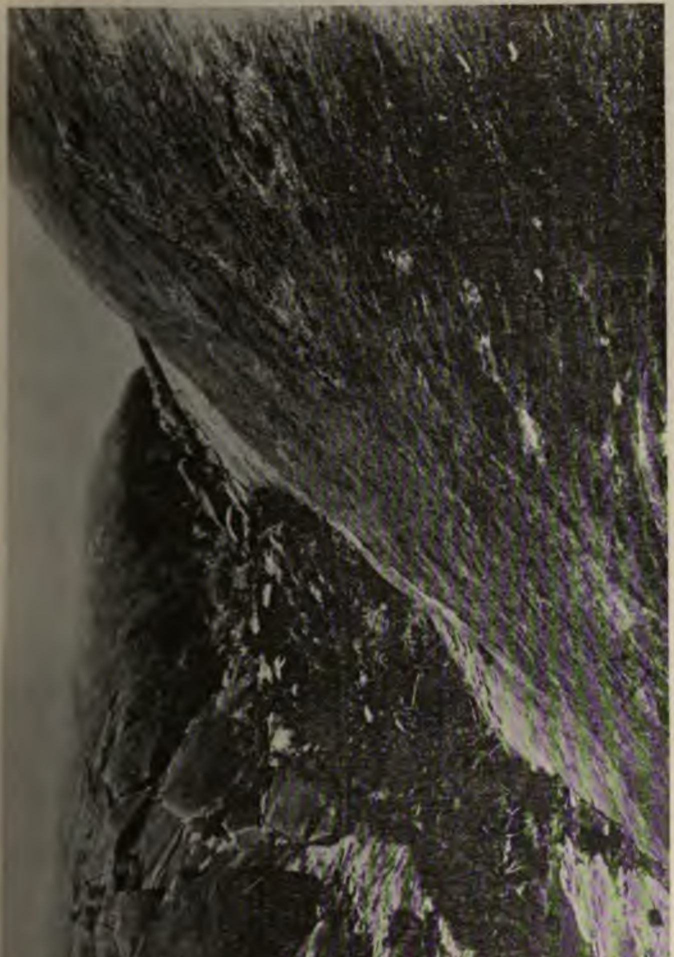


Fig. 10.

Photo: T. Blatchford. **Yorkrakine granite—block weathering.** Neg. 1313.

In summing up the evidence from the various granitic rock specimens submitted, Farquharson remarks as follows:—

> In external appearance the two groups are, as already stated, undoubtedly separable. When, however, attention is directed to the

the main constituents are the same, viz., quartz, microcline, and biotite, and in both the same peculiarities are manifested, viz., vermicular micro-pegmatite areas and inclusions or intergrowths of quartz in the

Fig. 11.

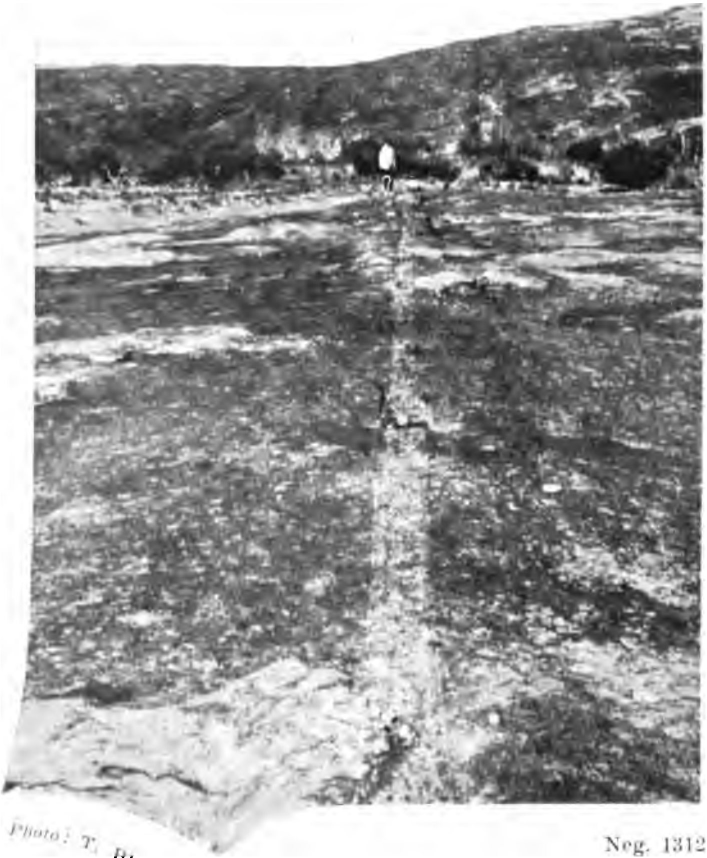


Photo: T. Blatchford. Neg. 1312.

Pegmatite dyke, Yorkrakine rocks.

felspar. There are differences between the group, but these, such as the presence of semi-porphyritic structure, the presence of green chloritic flakes, and the presence of pyroxene crystals in group (1), are of minor importance.

With regard to sphene, this mineral has not been observed in group (2), but, on the other hand, it is not observable in all specimens of group (1). Again, specimens like $\left[\frac{1}{781}\right]$, which, according to field evidence, are dykes and are connected with the granites of group (2) are, both in external appearance and in composition, strikingly similar to $\left[\frac{1}{745}\right]$. Since, therefore, the mapping shows the rocks of group (2) to occur as veins or apophyses, it is probable that the yellow specimens are but apophysal varieties of a main mass of which the rocks of group (1) are specimens. This being the case it would appear, further, that the quartz and quartz-felspar pegmatite that form the ore bodies of the main lode (Edna May) are genetically connected with the magma which gave rise to the grey granite (group 1). Owing, however, to the impossibility of obtaining further field evidence on this point, no positive assertion to this effect can be made.

GRANITIC BOSSES AND DYKES.

In the Westonia belt, apart from the massive granite, granitic rocks are well represented by bosses, dykes, pegmatites, etc. Owing to the frequency of occurrence, and to the fact that one variety is highly auriferous, the granite dykes have an important bearing in mining operations. It has been noted by the writer from personal conversations with mining men in general, on the field, that there is a great diversity of opinion as to what these granitic dykes really are and what their relationship is to the other members of the rock series. On this account, it is considered expedient to give here a résumé of the modern conception of their origin, with special reference to the more important pegmatitic forms.

In the area under review there are several distinct forms of granitic rock, the more important being:—

1. Bosses and arms of practically normal granite.
2. Coarse-grained pegmatites in which mica, felspar and quartz are in usual proportions.
3. Aplites, fine-grained granites, in which mica is absent, and in which the felspar is sometimes very coarse; in other cases, the quartz and felspar is scarcely separable in hand specimens.
4. A very acid form of pegmatite in which the felspar and mica are wholly, or almost wholly, absent, the dyke assuming the character of a quartz reef.

Of the first class, the best example of a boss is to be found at the back of the old townsite. Here we find a large conspicuous outcrop of normal granite which, with its arms, are wholly surrounded by greenstone. This boss is, without doubt, a portion of the main granite mass, which has broken up as an isolated mass in the greenstones. The tongues or arms branching from this mass are usually seen to be of the same nature as the main boss, though some of the smaller dykes are distinctly coarse-grained and pegmatitic in character.

On the main granite-greenstone contacts, numerous massive dykes of normal granite are found, which again must be placed as arms of granite directly connected to the main body.

These do not, as a rule, extend any great distance into the greenstones in the form of normal granite.

PEGMATITES AND APLITES.

These rocks, which occur more or less as narrow dykes, breaking through all the other types, with probably the exception of the sedimentary metamorphic series,* represent the last phase of intrusive activity in the Westonia district.

At the surface they are comparatively seldom seen outcropping for any great length but can, nevertheless, be often traced by scattered fragments for considerable distances. Sometimes areas are met with where the surface is littered with fragments of these rocks, and these are probably due to the disintegration of a dyke which has been lying more or less parallel to the surface, since it is found in the mine workings that many instances occur in which the dykes are almost horizontal.

That they are numerous is evidenced by their frequent occurrence in mine workings and bore cores.

They vary in size from thin veins one to two inches thick up to massive dykes of 20 to 30 feet in thickness.

In composition and texture there is also a wide range of variation, from coarse-grained pegmatites in which mica and felspar are both present or the mica absent, to fine-grained aplites almost felsitic and a combination of both in the one dyke, the felsitic portion forming the marginal facies. This variation in texture and composition is often coincident with the thickness of the vein.

Thus we find the thin dykes almost invariably aplitic and frequently felsitic in structure, and though certainly at times they are coarse-grained, in such instances mica is almost wholly absent, whilst the thicker dykes are persistently more regular in grain and the minerals more uniformly distributed. The latter are more closely allied to a normal granite in structure and composition, though the mica is always below the normal quantity. In several instances sections have shown the dyke rock with inclusions of the invaded rock thus proving the intrusive nature of the former. As regards the strike and dip of the acid dykes there is no general rule.

Certainly in the Edna May and Central mines several of the main dykes have a general north-east, south-west strike with a variable dip to the south-east, but when followed any distance even these dykes often vary in direction and dip considerably in a few feet. In the granitic areas where the massive granite comes to the surface such as at Yorkrakine rocks, etc., the pegmatitic structure of portions of the granite can be well observed. At Yorkrakine, in particular, one can see irregular masses of felspar and quartz with patches of biotite scattered throughout the rock mass. Such have not had the opportunity, when forming, of filling a crack and thereby forming a vein, but have crystallised out in the rock mass in irregular masses. However, in some cases such residuals have found a way into fissures, and are then seen as normal dykes. A photograph of one of these illustrates this point clearly*.

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* They have not been observed in the sedimentary area.

The chief point to note about their occurrence is their comparatively negative effect on the rocks they pierce. As has already been stated, they invade all the plutonic and intrusive rocks, also the quartz veins and lodes. It has been stated by some of the mine managers that local enrichments occur in the lodes near the position at which the dyke passes through the latter. Certainly in one portion of the Edna May lode this seems to be the case, but, as a general rule, this enrichment, if existing, is not so apparent as in other localities in the Yilgarn goldfield and, from a mining point, is almost negligible. With one exception faulting along the plane of the dyke is absent and, even in this exception, the throw of the fault is insignificant and has not caused the mining complications which have occurred under similar conditions for example, in the Marvel Loch district. In no instance are the acid dykes foliated.

The acid dykes in the Edna May, Central, and Deeps mines have nevertheless been, or will be probably, the cause of serious water troubles to mining operations. This question will be dealt with when writing about the mines themselves. Other than this, the acid dykes are of no significance from a mining point of view, for though they have been found carrying traces of gold, probably original, the gold has occurred in such small quantities as not to warrant serious consideration.

Farquharson, in summing up the white granites and aplites refers to them in the following terms:—

> In general, therefore, the rocks are white in colour, vary in grain from fairly coarse to a fineness which is almost felsitic. They consist of felspar and quartz, the former being, in places largely microcline, but in places orthoclase, and another acid plagioclase. Only rarely do a few scales of brown biotite and green chlorite appear. In one instance, *i.e.*, at 243ft.-251ft. in the No. 3 bore (Edna May), the granite or aplite contains small red garnets.

For detailed references see appendices.

The local names for these dykes is legion. For example, when mica is conspicuous in a dyke it is designated a "mica bar," aplites when fine-grained are often known as "quartzites," whilst if the felspar in the coarse varieties is at all conspicuous "limestone" is not at all an uncommon name. It is evident, therefore, that in some cases at least, there is a rather weird conception as to the nature and origin of pegmatites and their allied forms.

The fourth and most important variety of pegmatites is the ultra acid or quartz form, the quartz reefs of the Edna May group which are the important lodes of the district.

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* Fig. 11.

It will be patent to any reader that the bosses and normal granite arms are merely portions of the main granite mass which have broken through the greenstones in the ordinary well-known manner of invading rocks. The occurrence is simple and the rocks easy of recognition.

This does not hold for the pegmatites which vary so much in texture and composition, especially in the extreme phases. For many years the origin of pegmatites, and incidentally of the ultra acid or quartz varieties, has been the subject of much controversy amongst numerous writers on the subject. In fact, the literature on this topic is so extensive that it is impossible to more than briefly summarise the individual theories. Taken collectively, there seems to be a consensus of opinion, especially amongst modern writers on the subject, that in any rock mass, before solidification, the component minerals are liable to separate more or less one from the other, and thus form zones in which certain minerals are predominant. This is known as differential crystallisation. On cooling, these segregated products crystallise out or solidify in certain order, the more acid constituents being the last to solidify. Such is termed magmatic segregation. Hence in a granite magma or molten mass the acid or quartz portion would be the last to solidify. Furthermore, an important factor in the solidifying of any rock mass is the casting off by the portion solidifying of surplus water vapour which, mixing with the siliceous or quartz residuum, makes the latter more mobile.

Vogt,[*] in criticising this process, writes:—

> By reason of the greater superior mobility of the aqueous solutions as compared with the magma, these segregations may send out branches in the form of the finest apophyses;

A second theory, which has few supporters, as to the origin of pegmatites has been advanced by Williams[†] from his study of the occurrences in Maryland. These investigations led him to the conclusion

> that both segregation and intrusive pegmatites quite similar in appearance appear side by side.

Crosby and Fuller[‡] disagree with Williams, and consider but one origin "the end product of differentiation"; further, that

> In every pegmatitic district there is one normal plutonic rock of essentially similar, but slightly less, acid composition, and with which the pegmatite is most intimately associated, into which it may be traced, and from which it has evidently been derived

Spurr[§] states that

> the modern conception is that, in a broad sense, the pegmatites are igneous rocks, but it is the part which water has played in their formation that has so strongly differentiated them from other igneous types.

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[*] Problems in the geology of ore deposits, Trans. XXXI., p. 133, 1901.
[†] General relations of the granitic rocks in the Middle Atlantic Plateau. 15th Ann. Rep., U.S. Geol. Surv., pp. 657–684 (1893–4).
[‡] Origin of pegmatites Technology, Quart. Vol IX., pp. 326–356 (1896).
[§] U.S. Geol. Surv., Prof. Paper 55, pp. 327 (1906).

The same author, in summing up the evidence as to the origin of quartz veins of magmatic origin, contends that:—

> Pegmatites are coarsely crystalline rocks which show close relationships with ordinary igneous rocks, such as granites on the one hand, and with veins, such as are known to be due to precipitation from aqueous solution, on the other. Hence there has been much perplexity and contention, some referring them to the igneous rocks and calling them dykes, others insisting that they are aqueous and true veins. But the latest essays on the subject agree that pegmatites are formed intermediate between those which govern the formation of siliceous "igneous" rocks like granite, and those under which quartz veins are formed. There is, in short, no line of demarcation in nature corresponding to our artificial and arbitrary one between igneous rocks and certain aqueous veins, between granite and certain masses of quartz.*

In support of the above theory it may be well to note here that, in certain cases, granitic dykes have been definitely followed through the successive stages to pure quartz.

One local example of this has been already noted by the writer in the Londonderry district.†

Apart from the foregoing classification of the various granitic dykes, bosses, etc., according to their composition and physical characteristics, a further and fairly definite separation may be made when their relative geological ages are considered.

Considered from this point of view they naturally resolve themselves into two, probably three, series.

Of these, the oldest would be those belonging to the bosses and granite dykes, and arms contemporaneous with the formation of the main granite mass.

Probably later, and certainly not earlier than this, the formation of the pegmatitic quartz reefs in the Edna May gneiss took place, whilst at a much later date we have most of the aplites and pegmatites which are found passing through all the other rock formations and thereby representing the last stages of intrusive activity on the field.

Microscopic descriptions of samples taken from the individual rock types are to be found in the appendices.

Further details of the occurrences of the aplites and quartz reefs will be given in discussing the individual mines.

BASIC DYKES.

In the Edna May group of mines several basic dykes have been intersected in the various underground workings and bore cores. Furthermore, in several instances basic rocks have been encountered and partially, but not completely pierced, thus leaving it in doubt as to whether such occurrences are of the dyke class as in the first case, or whether they represent portions of the main basic rock. In each instance when a sample of basic rock was obtainable it was microscopically examined, and this has led to the following classification of two distinct varieties, with a possible but doubtful third:—

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* Spurr—Igneous rocks as related to occurrence of ores. Transactions Am. Institute, M.E., Vol. 33, pp. 312.

† Bull. 53, G.S.W.A., p. 17. Perth: by Authority, 1913.

Type 1:

Under the heading of basic rocks reference was made to a band of hornblendite lying on the footwall of the Edna May gneiss.

Type 1 represents a similar class of rock in the form of (A)* an undoubted dyke, (B) several intersections of basic rock which are probably portions of the hornblendite band.

The dyke lies in the south-eastern portion of the Edna May mine, at the end of the main lode.

It has been intersected in the following mine workings:—

Edna May:

150ft. level—Number 3 south crosscut, and south crosscut near main shaft.

225ft. level—South-west crosscut and south-east crosscut.

300ft. level—At end of main crosscut.

Edna May Deeps:

485ft. level—in No. 1 winze, near main shaft.

In no case has the thickness of this dyke been greater than 4-5 feet, while at the 300ft. in the Edna May it is not more than two feet.

The rock throughout is slightly foliated, the planes of foliation being parallel to its walls. This is probably due to shearing.

At the 485ft. level in the "Deeps" the rock is comparatively fresh, but from the 300ft. upwards is patchy, some portions being friable to the touch.

So far, this dyke has been an important factor in both mines, as it apparently controls the south-western extension of the main lode.

In the ends of the west drive and main crosscut in the Edna May at the 150ft. level, the depressed bore 300ft. level Edna May, the depressed bore in Deeps from the 240ft. level and the footwall of the 485ft. level Deeps, a similar rock to that of the dyke rock has been cut but not passed through.

Some doubt exists, of course, as to whether such occurrences may not be dykes, but, in the writer's opinion, they will probably prove to be the intersections of the hornblendite band previously referred to. There is so strong a resemblance between the rock at these intersections, the dyke and the hornblendite, that they must all be classed as one and the same rock and, therefore, as different from the prevailing foliated hornblende-felspar types. As regards the age of the hornblendites, there is no doubt that they are later than the Edna May gneiss and the Edna May Central

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* Plates XV. and XVI.

Deeps lode, for the dyke can be seen in its passage through both of these rocks. They are, however, older than the aplites, for the latter clearly pass through the hornblendites.

Further reference will be made in the descriptions of the individual mines as to their possible influence over the lodes.

Type 2:

This class is represented by one dyke which is found in the depressed bore in "Deeps" at a vertical depth of 344 feet, in the Edna May "Deeps" shaft at 344 feet, and Duff's bore at a depth of 304 feet.

According to the depths at which this dyke has been cut, it follows that it must be approximately horizontal with a slight dip to the north-west. A good section is to be found in "Deeps" shaft, where its intrusive nature is clearly seen, the planes of foliation of the dyke being at an angle readily distinguishable from those of the gneissic granite (Edna May gneiss).

Apparently the average thickness is from two to four feet. As far as is known, it is unimportant from a mining standpoint. The rock has been classified as a variety of amphibolite in which the felspar and hornblende occur in varying proportions.

Type 3 (doubtful):

Passing through the Edna May lode is a narrow, extremely weathered basic band of rock, an undoubted basic dyke. Unfortunately in no case could specimens be gathered from its intersections, which were sufficiently fresh for decisive microscopic diagnosis. The dyke is unimportant, and passes out of the mine workings at the 245ft. level.

In the appendices full microscopic descriptions are to be found, whilst in the plans and sections the course of the dykes, etc., have been portrayed.

In addition, the official numbers thus [$\frac{1}{872}$] have been placed on the plans, and these will be found to correspond with those in the appendices.

SUPERFICIAL DEPOSITS.

Scattered over the greater portion of the field are deposits of "cement," loose loam, sand, etc., the result of the wearing away of underlying rocks by comparatively dry denudation. At times these take the form of lateritic deposits, both the siliceous and ferruginous varieties being represented. Laterites are, however, comparatively rare and, when found, usually occur in isolated patches on the higher ground, and represent the remnants of probably very much more extensive beds.

Little is known about the depth or character of the superficials. It is characteristic of the siliceous laterites to overlie granite, and almost equally so for the ferruginous varieties to be found on the top of the more basic rocks. However, the resorting and redistribution of the laterites and the formation thus of the lower level lateritic deposits from their original formations often tends to these general rules being broken.

The auriferous nature of surface deposits has already been referred to in a report on the southern area of the Yilgarn goldfield at Marvel Loch.[*]

The one instance in which payable gold has been discovered in an alluvial deposit at Westonia occurs in the Edna May Central mine. Reference to the extent and nature of this deposit will be found included in the detailed description of that mine. Suffice it to say here, the evidence is such as to demonstrate that the detritus in the deposits has not travelled any great distance or been subject to any definite sorting, for in no instance were the pebbles found to be anything much more than sub-angular, and they were invariably intermixed with the kaolin and ferruginous material, forming an indefinite mixed deposit. Gold is found both in the quartz pebbles and cementing material, the richer sections being where the quartz pebbles predominate.

X.—MINES OF THE BULLFINCH BELT.

The mines of the Bullfinch belt may be classified under three headings, according to the nature of the ore-bodies being worked:—

(1.) Those containing quartz-haematite schists.
(2.) Those containing dolomitic lodes.
(3.) Those containing quartz reefs and veins.

QUARTZ-HAEMATITE SCHISTS.

On plates 6, 7, and 8 it is evident that this class of lodes extends throughout the whole length of the northern portion of the Yilgarn goldfield, and continues southward as far as Cheriton's.[†]

The series, with minor exceptions, persistently hugs the eastern granite contact. Though, as a general rule, auriferous, the deposits seldom contain sufficient gold to be payable as mining ventures. Certainly the Bullfinch "main" and "southern series" of lodes have been profitably worked, but these are exceptions to the rule, the enrichment being due to extensive local faulting.[‡]

This faulting has rendered it possible for solutions to circulate through the original ore-bodies, and by this agency certain zones in the lodes have been considerably altered. Incidentally, during this process the gold contents have been concentrated.

Like conditions have not been noted in any other area than the Bullfinch along this extended zone in which the quartz-haematite schists occur. Certainly, in some of the blanks on the plates referred to, similar conditions may exist and be still covered over, but such are not evident at the surface. In fact, rather the reverse was noticeable, the regularity of the deposits being most pronounced.

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[*] Bull. 63, p. 101. Perth: by Authority, 1915.
[†] Bull. 63.
[‡] *Vide* Plate XI.

DOLOMITIC LODES.

Of the dolomitic deposits one only has been worked, viz., the "northern series" of the Bullfinch mine. This lode has been the mainstay of the mine and has been developed to a vertical depth of 500 feet. The lode is a typical example of replacement, and although the gold contents are largely dependant on a secondary enrichment, due to the introduction of quartz veins, the deposit as a whole is an important addition to the other varieties of gold-bearing lodes of the district.

QUARTZ REEFS AND VEINS.

There are three varieties of quartz reefs represented.

First there are the large low-grade quartz reefs, such as at Hope's Hill, Corinthian, etc. Associated with these are narrow quartz veins usually carrying higher gold values, but small and usually erratic in habit. Closely allied to these are the quartz veins so common in the southern areas and invariably found associated with the quartz-haematite schists. The occurrence of these in the northern area is not nearly so common as in the southern portion of the belt; yet they are of extreme importance to the prospector, producing at times considerable quantities of remunerative milling stone. One or two minor examples of quartz veins in acid dykes have been noted but are not of any great importance.

The following are detailed descriptions of the mines which were accessible for inspection. Unfortunately, these were few in number, most of the old workings opened up in the boom days having been abandoned.

It should be noted that, without exception, all the gold-producing lodes and veins lie in or near the zone in which occur the quartz-haematite schists. Furthermore, the only rocks which carry gold-bearing lodes are the greenstones, and in one instance an acid dyke, the massive granite and sedimentary series so far being proved to be barren.

Corinthian and Corinthian North Gold Mine, G.M.Ls. 896, 893.

Location.—This mine is situated at a distance of 11 miles north of Southern Cross and lies one mile to the west of the Bullfinch-Southern Cross main road.

Geologically, its position is on the contact of the main massive granite and the greenstones.

Geology.—Several distinct groups of rock occur on the above leases.*

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* *Vide* Plate X.

(a.) Granite.—Massive granite of a distinctly gneissic type lies to the immediate east of the main workings and forms the footwall of the lodes. The gneiss is probably the selvedge of the main Southern Cross granite.

(b.) Foliated amphibolites (greenstones) form the western or hanging wall rock. This rock has been fully described in the previous pages of the present report under the heading "greenstones."

Occurring as they do on the Corinthian leases, the rock presents the phase of extreme foliation, especially in the immediate vicinity of the lodes.

(c.) Granite dykes.—These are represented by two narrow dykes in the 100ft. workings. The felspars have been completely weathered and the rock is only recognised by the disintegrated grains of quartz. Mica is almost wholly absent, minute traces alone remaining.

(d.) Dolerites.—Fairly fresh examples of this rock occur as dykes. Of these the main one is found outcropping to the east of the main shaft. It is also seen in No. 5 shaft at the 100ft. level, and in the main shaft at 200ft. level, where it attains a thickness of 24 feet. Four other dykes of a similar character are intersected in the main south drive at the 100ft. level. The general strike of all is north-west south-east with a dip to the south-west at a fairly steep angle. There is little doubt that these dykes are the newest rock of the series and will be found invading all other members.*

Lodes.—Sandwiched between the granite and amphibolites are extensive lenses of quartz and quartz-haematite schists.

Quartz-haematite Schists.—The quartz-haematite schists, which have the prevailing lens shape, represent a portion of the main series found in an almost continuous line from Cheritons to the northern extremity of the Bullfinch belt. Although classified here as a lode on account of the presence of gold and gold-bearing minerals, the rock is not being worked as such, being too low grade to be profitably treated.

The origin and nature of quartz-haematite schists has already been fully discussed.

Locally the rock is known as "biscuit rock" on account of the colour and the fact that in and near the surface the weathered portions break into flat yellow-coloured pieces, supposed by some to resemble certain forms of edible biscuits.

Quartz lodes.—These come under two headings—(a) the massive or main lodes; (b) smaller quartz veins or laterals.

Main Quartz lodes.—There are two main quartz lenses, striking approximately parallel to the granite greenstone contact and underlying very slightly from the vertical towards the west.

Of the two the northern is by far the most important and in it the main workings occur.

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* For further details see appendices.

Practically all the quartz for that portion of the lode in lease 896 and partly in the northern end of lease 893 has been open-cut to the 100ft. level and sent to the mill. The width taken in places was as great as 25 feet.

All this ore was oxidised. As the accompanying returns show, the gold contents were extremely low, yet payable. Unfortunately, sulphides made their appearance in the northern end of the drive at the 100ft. level, and although the top of the sulphide zone pitched away to the south, the stock of payable oxidised ore was thereby diminished, contrary to original expectations.

It seems possible that the zone of oxidation was influenced by the main dolerite dyke, and it will probably be found that the top of the sulphide zone is parallel to this dyke.

Below the 100ft. level in the sulphide zone, the gold values were found to be erratic in occurrence. At first it seemed as if they were also pitching south, but mine developments did not substantiate this idea, but rather tended to prove that the gold occurred irregularly in more or less flat indefinite zones. Unfortunately, before a conclusion could be arrived at on this point, the mine closed down. Even in the upper levels the southern portion of the main levels did not yield payable stone in any quantities under existing mining conditions.

For the most part the main quartz lens is a solid compact body of stone, but in certain zones, especially near the boundary between the two leases, it is much broken. As this particular spot is not far removed from the four dolerite dykes previously referred to, it is scarcely to be wondered at. There is no sign of local enrichment in this vicinity.

Marcasite, pyrrhotite, and ordinary pyrites are the principal sulphide minerals in the sulphide ore.

Pyrrhotite occurs in such quantities as to seriously hamper the extraction of the gold by direct cyanide treatment. The minerals are, as a rule, fairly well distributed throughout and occur in small veins and bunches.

Quartz veins.—Several quartz veins have been found on the western side of the main channel. Two at least of these are probably connected directly with the main lens, but the others are parallel veins filling minor shear planes in the adjacent greenstone. Though of a higher grade in gold they are too small to be of any intrinsic value to a large low-grade mining concern.

Treatment.—The oxidised ore was rough crushed in an ordinary wet stamp mill, fine ground in two tube mills 16 feet by four feet, then direct cyanided and finally treated in an improved Ridgeway filter.

When it became necessary to treat the sulphide ore, two Newell No. 8 ball mills were installed, the ore dry ground, and roasted in two Edwards' furnaces having a length of 149 feet with 60 rabbles each. The after treatment of the sulphide ore is similar to that of the oxidised portion.

That this venture was not a success is regrettable from several standpoints, one amongst others being that the proposition was one of the lowest-grade mines of its class in the State. Had it been successful it would certainly have given encouragement to prospect and develop similar deposits elsewhere.

Table showing the Yield of the Corinthian Reef.

Year.	Name and Number of Lease.	Ore Crushed.	Gold therefrom.	Total.	
				Ore Crushed.	Gold therefrom.
		tons.	ozs.	tons.	ozs.
1909	Corinthian, 893	42·00	30·86	..	..
1910	Do.	145·00	138·65	..	..
1911	Do.	1,075·00	567·50	..	..
1912	Do.	..	..	..	..
1913	Do.	1,422·50	386·79	..	..
1914	Do.	..	..	..	..
1915	Do.	..	..	..	..
1916	Do.	..	..	2,684·50	1,123·80
1913	Corinthian North G.M., Ltd., 896, 934, 946	18,713·00	4,320·01	..	..
1914	Do. do. do.	48,730·00	10,149·25	..	..
1915	Do. do. do.	47,147·00	9,218·17	..	..
1916	Do. do. do.	16,632·00	3,876·89	131,222·00	27,564·32
	Total	..	..	**133,906·50**	**28,688·12**

BULLFINCH PROPRIETARY GOLD MINE, G.M.Ls. 960, 916, 915, 926, 928, 914, 942.

Location.—The Bullfinch Proprietary gold mines are situated near the township of Bullfinch, which lies near the Southern Cross-Jackson road at a distance of 22 miles north of Southern Cross.

History.—Gold was first reported as having been discovered in the locality by C. Jones, the working partner of a syndicate formed by D. L. Doolette and others to prospect the country north of Southern Cross.

Jones' application for a mining leases was lodged at the Warden's Court, Southern Cross, on 29th December, 1909. As the first parcels of ore yielded extremely high returns a phenomenal boom in mining occurred throughout the whole district, the far-reaching effects of which have already been referred to. Shortly after the leases were pegged a company was floated and mining operations commenced on a systematic scale, the mine eventually turning out to be an extensive and consistent producer though, unfortunately, the grade proved to be much lower than originally anticipated.

Geology.—Two distinct series of rocks are represented, the one granitic the other basic.

Of these the former is represented by the main Southern Cross granite. As at the Corinthian, this granite is gneissic and probably represents the foliated selvedge of the main mass. Narrow granite dykes, so common in other places, are absent in this locality.

Basic Rocks.—The basic rocks, commonly known as greenstones, contain the lodes.

There are various points at issue as to the age, origin, and classification of these basic rocks. Gibson, whose private report on the mine has been kindly lent to the department, divides the basic rocks into two—a "newer" and "older" series—the former having intruded the latter.

The "older" he classes as being originally fine-grained diabases, now in the form of schistose epidiorites as the result of dynamic metamorphism.

The "newer," which is essentially coarse-grained, uralite amphibolites and talc schists sometimes massive but usually schistose, he considers the resultant of a coarse-grained pyroxenite.

Farquharson, dealing with the same rock specimens, classifies them as fibrous epidiorites or hornbendites, all of which have been derived from gabbro or pyroxenites.

Certainly in the main crosscuts of the mine in the deeper levels where the rock mass can be best studied, there seems to be no apparent demarcation between the various forms, the one merging into the other and repeating in the same section as if they were altered portions of one rock mass. Near the "northern series" lode there is certainly a narrow band of fresh epidiorites which may be of later age than the rest of the complex, though on the other hand it may be an unsheared portion of the main mass; the latter case being the more probable. For a fuller discussion on the subject, *vide* Appendices. The greenstones have been mapped on Plates VII. and XI. as derivatives from the same magma.

Lodes.—The lodes of the Bullfinch mine come readily under two general headings:—

A.—Quartz-haematite schists and their equivalents.
B.—Dolomite lodes.

A. *Quartz-haematite Schists, etc.*—The origin of the quartz-haematite schist deposits has already been fully discussed and need only be briefly referred to here. They represent the altered product of crushed zones in the greenstones by replacement with silica and various iron oxides.

In the Bullfinch series several distinct forms of these lodes occur varying from the typical haematite variety to one consisting of silica with a very small percentage of iron.

Of these, the three best defined groups in the mine are locally known as the "Discovery lode" or "Southern series," "The Main Lode," and the "Water shaft" lode. In addition, there are certain "pipes" of gold-bearing ore to which no name has been given but which are genetically connected to the above.

The extent and position of the various lodes may be seen on Plat VI., where a plan of each level from the 100ft. downwards has been drawn. On the surface little of the lodes can be seen at present as the outcrops are partially or completely covered with surface detritus.

Faults.—At the 100 feet level in particular, a main fault plane is seen striking north-east, south-west through leases 914 and 915, the dip being to the north-west. Past this fault plane the southern series has not been found extending to the south-east. The same fault plane is found near the eastern end of the "main lode."

It is probable, but not certain, that this fault plane extends past the eastern end of the northern series.

Minor faults are found cutting the main series off at the eastern end (No. 1 fault), whilst between this and a second fault (No. 2) a short lode occurs which is probably a faulted portion of the main series. Between the main fault and No. 3 fault another similar lode, probably a faulted piece from the northern end of the main series, occurs.

Faults 1, 2, and 3 have a general north by east strike with a dip to the west by south. The water-shaft lode is cut off by fault No. 4, which strikes north-west and dips south-west. Besides these, there are several minor faults, as shown on Plate XI.

The Discovery Lode.—This consists of an extensive series of parallel lodes occurring in bands of a varying composition, but which in a geological sense, must be considered as one deposit. On account of the variation in gold values, however, only certain portions are mined and, for this reason, the series, for convenience sake, has been divided into two, the "southern series" and "yellow lode."

The Yellow Lode.—In the upper levels this consists of a band of hard, yellowish, laminated quartz. Evidence of brecciation in places is well marked.

At the 100ft. level the yellow lode has not been developed to any extent. A crosscut in the eastern end shows a width of lode of 21 feet. The lode here has been driven on for a total length of some 100 feet.

200ft. Level.—The lode here has been driven on for a considerable distance. In the crosscut the width is some 15 feet. The ore is oxidised still, but sulphides are just making their appearance.

300ft. Level.—The lode at this level contains a fair percentage of sulphides and is well in the sulphide zone. Where intersected in a crosscut the thickness of the ore has been proved to be about the same as in the upper levels.

Southern Series proper.—This series consists of parallel bands of iron-bearing quartz schists, separated by layers of soft clay schists, which are also more or less ferruginous. Of these, the most southern portion is a compact hæmatite-bearing lode, a typical example of the quartz-hæmatite variety. Except that the iron contents are not so pronounced the other portions of the southern series are of a similar character. They consist mainly of a sintery, crushed, and at times brecciated laminated quartz. At the 200ft. level iron sulphides make their appearance, but even at the 300ft. level the iron oxides are not wholly replaced by such. The sulphides occur in patches, some portions of the rock being highly charged with them, whilst in other places the lode is, apparently, still practically in an oxidised state.

There is a pronounced falling away in the silica contents of the lode in the lower levels, and one forms the impression that the percentage of the country rock constituents is gradually increasing.

At the 100ft. level extensive stoping has taken place on the main fault. Here stopes are seen with dimensions of 120 feet by 170 feet; they are irregular, however, and will probably not average more than 40 feet. There is a gradual falling away in gold values in direct ratio to the distance from the main fault.

200ft. Level.—At the 200ft. level no stoping has been done. The lode here has a width of 90 feet. Sulphides make their appearance at this level.

300ft. Level.—As at the 200ft. level nothing but development has been done here. The lode has the same thickness and is partially oxidised still, though sulphides are more prevalent.

Owing to the great size and irregular nature of the ore body, the pronounced pitch of the fault plane and consequently the stopes, to the north-west, square setting in the stopes was the form of timbering resorted to and has been used throughout this section.

Water-shaft Lode.—This was a narrow pipe of ore stoped down on No. 4 fault plane to the 100ft. level, the dimensions of the stope being 40 feet by 50 feet. Below the 100ft. level no work has been done on this ore body. At the surface the fault plane (No. 4) is represented by a narrow band of quartz-hæmatite schist, which does not contain appreciable gold values. This band is visible on the north-western side of the open cut.

Main Series.—At the surface this lode outcrops as a quartz-hæmatite schist, the eastern extension of which has been faulted on fault plane No. 1; this faulted portion is low-grade. The main series, otherwise known as the rich shoot, is a band of altered quartz-hæmatite schist about 130 feet in length and worked for a width of from 15 to 20 feet. It lies between the main and No. 1 fault planes. The fault plane (No. 1) is now represented by a narrow band of very ferruginous quartz-hæmatite schist. Especially in the upper levels the lode is much shattered and altered, the fracturing being no doubt caused by earth movements along the fault planes.

This shattering made the lode pervious to circulating solutions, which not only removed the soluble portions of the lode but, at the same time, replaced such with silica and iron compounds in the form, probably, of sulphides.

The sulphides thus introduced contained gold and have since been oxidised and leached away, leaving in places an almost pure sintery quartz and the gold in a free state. In appearance some of this quartz resembles closely that found in the upper levels of the Mount Morgan's mine in Queensland. It is extremely porous and resembles a pumice or sponge in structure, in many instances being easily crushed in the naked hand.

Gibson, who reported on the lode in its early stages, describes it thus:—

> In its present highly oxidised state the lode (rich portion) consists of an irregular, more or less rubbly mixture of quartz, ironstone, and clay schists, the ironstone predominating. Occasionally it is hard and compact, consisting of brecciated portions of the original lode cemented together with secondary or ''jasperoid'' quartz. There are no defined walls, and irregular veins of quartz and ironstone run out into the shattered country on either side, the latter often carrying fairly high gold values.

The lode underlies to the south-west slightly but pitches to the north-west on the fault plane at an angle of about 45 degrees. Stopes extend from the 100ft. to the surface. The two faulted ends, *vide* Plate XI., have not been mined.

200*ft. Level.*—The "rich shoot" is 130 feet long at this level and has a stoping width of 15-20 feet. A fair amount of iron sulphides make their appearance in a winze at the 235ft. level.

In composition the lode is similar between the 200ft. and 100ft. levels to that at the 100ft. level, with the exception of the sintery quartz which is, apparently, not so pronounced.

300*ft. Level.*—The structure of the lode here is similar to that above. Sulphides are pronounced throughout the ore body. The length of the ore body is 150 feet, with stoping values over a width of from 12 to 15 feet.

400ft. Level.—At the time of inspection the lode had only been partially opened out at this level. The characteristics were very similar to those of the 300ft. level.

Immediately under the main fault plane the country rock is much weathered and, apparently, in the initial stages of the formation into a quartz-hæmatite schist. As a whole, this impregnated zone does not contain sufficient gold to render it milling ore; pipes of ore occur in it, which have, however, proved payable.

Starting from No. 10 shaft, one of these pipes has been stoped for a length of 70 feet by 25 feet. This pipe dips to the south-east and comes into the 200ft. level in the east drive, where the stoping width is 70 feet by 30 to 40 feet.

The same pipe has, apparently, been intersected in the South cross-cut at the 300ft. level and risen on in No. 8 rise. The stoping dimensions at this level are 40 to 50 feet by 8 to 10 feet. The dip of this pipe can be seen on the accompanying plans.

Another similar pipe of ore, 20 feet by four feet, has been followed from the 300ft. level in No. 4 rise up under the west branch drive at the 210ft. level.

It is probable that if this pipe be followed it will remain under the main fault plane and come up into No. 2 level with the lode found at the east end of west branch drive. This pipe is heavily charged with sulphides.

Summary.—The main and southern series may all be classified as or modifications of the quartz-hæmatite variety of lodes. As such the general tendency is that the lodes contain less gold as greater depths are reached. There is no direct evidence to hand regarding the exact nature of these deposits at depths exceeding 400 feet, but the general tendency is for the lodes to lose their characteristics and, presumably, gradually merge into the country rock. The Bullfinch mine, being one of the best examples opened up, should be carefully studied in the future if development be carried to deeper levels.

Northern Series.—The northern series is a lode unique in character as regards the mines of the Yilgarn Goldfield in that, below the oxidised zone, it consists almost entirely of dolomite.

This lode does not outcrop at the surface. At a vertical depth of about 120 to 130 feet there is a sudden change in the lode from a siliceous to one of a dolomitic character. At the same level the sulphide zone is reached.

100ft. level.—At this level the lode consists of one ore-body striking north-west-south-east with an underlie to the south-west.

The south-eastern end apparently lies on the main fault of the southern and main series and pitches to the north-west. Whether the north-western end has gradually ended in a feather edge has not been proved.

In the lower levels an eastern "leg" was discovered. To ascertain whether such occurred in the 100ft. level a crosscut was driven north-east to intercept this "leg," but was unsuccessful.

From the 100ft. level stopes have been extended to a height of 45 feet, when the ore-body cut out.

The lode from the 100ft. upwards, and to a depth of 20 to 30 feet below the level, consists of a mixture of ferruginous clayey lode material partially cemented together, with irregular masses of jasper, the whole ore-body being traversed by narrow quartz veins. These veins are comparatively flat with a general north-west south-east strike and an underlie to the north-east.

The hanging wall is much decomposed, and consists of a highly schisted rock, the weathered product of an epidiorite or allied rock. In places the demarcation between the hanging wall and the lode is not too distinct, the same remarks applying to the footwall, though not to the same extent.

The stopes are kept open by square setting.

200*ft. level*.—In the 200ft. level the lode assumes a horseshoe shape, the longer arm of which is the western.

Throughout both arms the lode consists of a compact dolomite, which the flat quartz veins pass as in the oxidised portions of the lode. An analysis of the dolomitic portion gave the following results:—

G.S.M. 1/826. G.S.L. 8886D.

SiO_2	15.83
Al_2O_3	.29
Fe_2O_3	.11
FeO	4.86
MnO	.27
MgO	17.21
CaO	27.64
Na_2O	.18
K_2O	.06
H_2O hyg.	.06
H_2O comb.	.80
TiO_2	.02
CO_2	31.99
P_2O_5	.07
Fe_7S_8	.48
Cr_2O_3	nil
V_2O_3	.04
	99.91

Gold—15 grs. per ton. Sp. gr.—2.94. Analyst, H. Bowley.

The chief constituents are dolomite, about 55.2 per cent.; calcite, about 14.3 per cent.; actinolite, about 25 per cent., with smaller amounts of pyrrhotite and probably serpentine, albite and quartz.

The above analysis tends to prove that the lode is a replacement one in a probably partially closed fissure, the foreign minerals, actinolite, etc., representing the remnants of the original rock.

There is no hard and fast line between the portion of the lode being mined and the walls of the country rock, the carbonation having extended a much greater distance into the latter than indicated on the plans on Plate XI. In many instances the quartz veins also extend beyond the zone of mining operations into the walls. From the 200ft. level downwards the walls are solid and comparatively not been subjected to surface weathering. Hence the trouble experienced in mining the lode in the upper levels is greatly diminished.

300*ft. level.*—There is practically no change in the nature of the lode or walls at this level from that below the 200ft. level. Stopes extend on both legs upwards.

400*ft level.*—In the western leg of this level a split in the lode is noticeable, a "horse" of country rock coming into the channel. This horse may also be seen in the stopes above the level.

510*ft. level.*—The ore-body had been cut but not opened out to any extent. Except that the quartz veins and sulphides were not so pronounced, there is no other change from the 300ft. and 400ft. levels.

General distribution of Gold and Mineral Contents.—There is no doubt that the gold and mineral contents are closely associated with the quartz veins. Both in the oxidised and sulphide zones it is very apparent that at the junction of the quartz veins with the lode proper, and extending into the walls of the veins, the greater portion of the mineral exists. It is also apparent that the quartz veins are of a later age than the main ore body. In the oxidised portions of the lodes there is an abundance of iron oxides scattered throughout, with isolated concentrated patches of a more or less silicеous nature. In these concentrations, which are uually associated with quartz veins, carbonates of copper are not infrequent, and, in isolated cases, native silver is present. Carbonates or sulphates of lead were not noticed, though it is almost certain that the silver has been liberated from the oxidation of galena, which is a common occurring mineral in the sulphide zone. In the sulphide zone the iron and lead minerals appear as streaks and bunches chiefly, as already stated, on the contact of and in the walls of the quartz veins. The dolomitic portion of the lode has usually a greenish tinge, which is due either to the ferrous iron or vanadium, possibly both.

Closely associated with the galena are various sulphides of iron, chiefly pyrites; probably marcasite and pyrrhotite.

No doubt the gold is associated with the basic minerals, for it is a general maxim on the mine that where there is no quartz showing, and mineral contents scarce, the gold values are low.

Unfortunately, figures regarding the gold from the various lodes cannot be obtained.

The mine's total production, taken from official returns, is:—

Tons (2,240lbs.).	Gold (fine ounces).	Silver.
24,842.94	117,404.26	16,442.43

Of the above amount, the first 1,027.52 tons produced 10,958.88 ounces of fine gold. This ore was taken from the main series in the early stages of development and speaks for itself as regards the richness of the first ore won from the mine.

Table showing the Yield of the Bullfinch Proprietary.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	ozs.
1910	Bullfinch leases. 914/6, 926, 928, 942, 960	1,027·52	10,958·88
1911	Bullfinch Proprietary (W.A.), Ltd., 914/6, 926, 928, 930, 942, 960 ..	653·42	5,544·42
1912	Do.	..	..
1913	Do.	47,959·00	33,760·96
1914	Do.	66,430·00	25,682·98
1915	Do.	68,636·00	23,631·17
1916	Do.	63,715·00	17,825·85
	Total	**248,420·94**	**117,404·26**

In conclusion I wish to acknowledge the courtesy and help shown me by J. Morgan, underground manager, and J. V. Rowe, surveyor. The accuracy of the fault plan is largely due to the latter, and may be rightly looked upon as a result of our combined efforts.

GLIDEAWAY AND NEW GREEN HARP GOLD MINES, G.M.Ls. 2272 and 2948.—As these two mines are on the same line of reef they can be conveniently described as one.

Geology.—Foliated greenstones and granitic dykes are the only two varieties of rock represented.

The lode, which does not outcrop at the surface but is overlain with about four to eight feet of surface soil, consists of a quartz reef lying between two perfect greenstone walls. The strike of the reef is some 30 degrees east of north with an underlie east of about 45 to 50 degrees. The width of the reef varies from a few inches to four feet. It has produced payable stone for a distance of 140 feet in the Glideaway, and about the same distance in the Green Harp. A main level at the 60ft. on the underlie passes through both mines. Most of the stone has been stoped above this level for a distance of 280 feet. In the Glideaway some stoping has also been carried on near the shaft below the 60ft. level, but these workings were under water on date of inspection, so dimensions were not procurable. The sinking of a main shaft on the Glideaway was the only work in course of progress on that mine. On the Green Harp a little work was being done to try and prove whether the reef was faulted or not in the south end.

As can be seen on plate (13) these mines are of interest from a geological point of view, in that the reef, contrary to the usual habit for the Yilgarn Goldfield, passes through numerous aplite and pegmatitic dykes, and is not invaded by them except, perhaps, in one instance.

In the Green Harp, in the southern end of the main reef, a large granitic dyke was met with. Whether this dyke has cut through the reef or not has not been proved. A parallel reef lying to the east has been worked, and it would seem that this second reef is the faulted end. On the other hand, there is no evidence of faulting in any other workings, or are there any indications of such movements at the surface.

It is therefore possible that the main reef extends southward past this dyke and that the eastern reef has no connection with the main reef, in which case the dyke would be of a later age than the reef and the main series of pegmatites.

The eastern reef has been opened out at the 50ft. level by a drive 45 feet south and a few feet north. Practically all the stone above the 50ft. level has been stoped, and the shaft filled in below. The strike of the reef is practically the same as the main reef, but the underlie is considerably steeper though in the same direction, viz., towards the east, at an angle of 55 to 60 degrees.

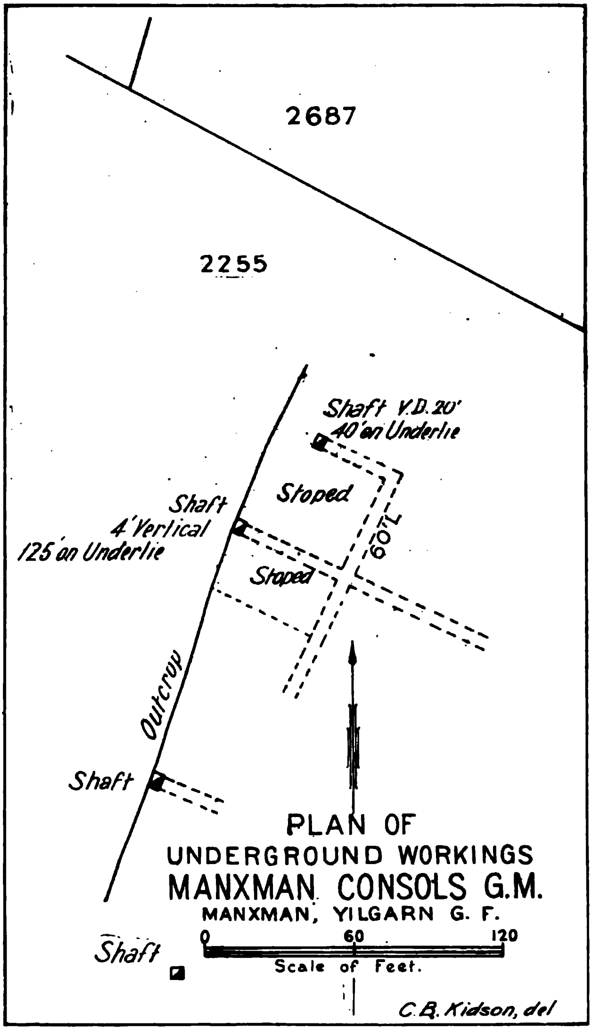
Table showing the Yield of the Glideaway, New Green Harp, and Green Harp Reef.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	ozs.
	Glideaway 2272	..	..
1912	Do.	254	360·52
1913	Do.	364	309·99
1914	Do.	233	331·32
1915	Do.	..	..
1916	Do.	..	..
1915	Green Harp, New, 2948	14	11·40
1916	Do.	..	..
1912	New Green Harp leases {2541 2542}	230·00	184·39
1913	Do.	379·90	211·13
1914	Do.	39·00	25·87
1915	Do.	17·00	9·31
1911	Green Harp 2297	46·00	53·21
	Total	1,576·90	1,497·14

Manxman Consols, G.M.L. 2790, Manxman Group (Plate VII. Yilgarn Goldfield.

Geology.—The country rock is similar to that of the Glide away and Rosalie gold mines, and consists of foliated greenstone i which are numerous granitic dykes.

Fig. 12.



Plan of workings, Manxman Consols.

The workings* of the Manxman Consols are in one of these dykes. Two small parallel quartz veins, known as the hanging and footwall "leaders," have been followed for a horizontal distance of about 70 feet and to a depth on the underlie of 125 feet.

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* Fig. 12.

The dip of the veins is from 45 to 55 degrees towards the east. A distance of from one to four feet separates the two veins. Throughout the workings the walls of the veins are very regular, particularly the footwall. The walls consist of a very fine-grained aplite, not oxidised to any great depth, and extremely hard to mine. It is difficult to form an idea of the average thickness of the quartz veins as the variation is from two inches to thirty inches in places. Where the vein increases in thickness the gold contents are said to be lower. Apparently the same granitic dyke in which the veins occur has been followed into leases 2296 on the south and [illegible] on the north. Gold has been found in a small vein in G.M.L. 2296, which has not been opened out to any extent, but was still being worked by prospectors with encouraging results.

Table showing the Yield of the Manxman Consols.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	ozs.
1914	Manxman Consols, 2790	4·35	6·98
1915	Do.	28·65	29·97
1916	Do.	8·00	12·36
	Total	**41·00**	**49·31**

ROSALIE G.M.L. 2739, Manxman Group, Plate VII., Yilgarn Goldfield.

Geology.—The Rosalie gold mine lies in the greenstones, which are much foliated and contain a network of acid dykes.

Mine Workings.—There are three main shafts on the lease.

South or No. 1 shaft.—This is an underlie shaft with a depth of about 90 feet. The inclination of the shaft is from 45 to 55 degrees to the east. At the bottom of the shaft there are no workings but 60 feet from the surface drives extend north and south. At the south end the reef is broken and small. The north drive has a length of 50 feet and follows the reef, which has a width of four feet at the shaft and about two feet at end of drive.

The end of this drive is about 15 feet from the central or vertical shaft.

The footwall of the reef is a very siliceous rock, probably one of the acid dykes. At times it is so siliceous as to be almost pure quartz. The hanging wall is greenstone, very schistose. A barren quartz vein occurs between the hanging wall and the payable lode. This barren vein is, in all probability, an acid pegmatite.

In the south end of south drive the footwall is greenstone.

No. 3 (*northern shaft*).—This shaft is also on the underlie at an angle of about 50deg. Depth on underlie, 105 feet.

At the bottom of the shaft the reef is six feet in thickness.

The strike of the reef is a few degrees to the east of north.

No. 2 *or Central shaft.*—This is a vertical shaft in greenstone, depth 40 feet.

From the north-west peg a narrow quartz vein has been traced on the surface and is said to contain payable gold values, but has not been developed except by costeans. This vein runs parallel with the main vein.

Table showing the Yield of the Rosalie Reef.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.	Total.	
				Ore crushed.	Gold therefrom.
		tons.	ozs.	tons.	ozs.
1912	Rosalie, 2391	23·00	23·98	23·00	23·98
1913	Rosalie, 2595	46·00	92·63	..	..
1914	Do.	18·00	33·94	64·00	126·57
1915	Rosalie, 2739	30·00	33·62	..	..
1916	Do.	90·75	88·65	120·75	122·27
	Total	..	..	**207·75**	**272·82**

VIOLET, G.M.L. 2653.—This mine is situated at a short distance to the north-east of the Golden Valley townsite.

Geologically, it lies in the main quartz-haematite schist series.

The main workings consist of an underlie shaft the vertical depth of which is 100 feet. At the 70 feet level drives extend 30 feet north and 26 feet south. This level is at the junction of the oxidised and sulphide zones. From the sides of the shaft oxidised ore has been stripped for a width of some twelve feet for a length of about 20 feet from the 70ft. level to near the surface.

The shaft is placed near the junction of a spur with a large quartz haematite lens which is not of any value itself as a gold producer.

Below the 70ft. level the spur lode, as seen in the shaft, contains sulphides, the quartz-haematite bands being highly charged with antimonial and arsenical sulphides.

A pronounced band of sulphide ore at the bottom of the shaft visible, the thickness of this band being about 24 inches.

The sulphide body is said to contain highly payable gold values.

The gold-bearing formation has the appearance of being a pipe the junction of the spur of the quartz-haematite schist with the h larger lens of the same nature. There is insufficient develop- nt to enable a definite opinion to be formed on this point.

It is evident that a considerable amount of crushing has taken e as the lode is fractured horizontally into a series of flat floors. is fracturing has possibly led to local enrichment.

Table showing the Yield of the Violet Reef.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	ozs.
1909	Violet, 835	65·00	133·26
1910	Do.	125·00	88·47
1911	Do.	50·00	45·31
1912	Do.	490·00	167·81
1913	Violet, 2653	60·00	12·80
1914	Do.	..	..
1915	Do.	23·64	43·32
1916	Do.	..	..
	Total	813·64	490·97

MARIONETTE, G.M.L. 2999.

Locality.—This mine is situated about 42 chains north of Trig. K48, which lies immediately to the north of Lake Deborah.

Geology.—The mine is in one of the quartz-haematite lenses of main series. On both sides this lens is encased with foliated hibolite.

The main workings consist of a vertical shaft, 60 feet deep. m the bottom of the shaft a short crosscut connects with two in drives extended 30ft. north and 40ft. south. For the whole ance the drives are in quartz-haematite schists.

rosscuts from the north and south ends and one opposite the t have been driven for a few feet towards the east.

In the one opposite the shaft and from the end of the south e a mixed quartz reef and quartz-haematite schist lode has been From the first an inclined rise has been worked to the surface, a winze extended 12 feet below the level. From the latter a ze has been sunk a distance of 15 feet, presumably on the same artz formation which has a thickness here of from four to five et. Sulphides show their presence in this winze. A series of partings occur in the quartz lode; these partings underlie to the east at a low angle.

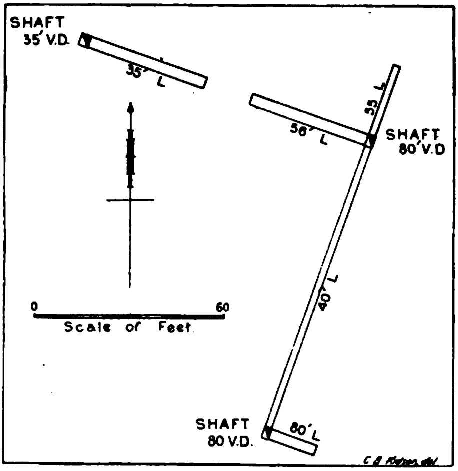
Gold is said to occur in payable quantities across the whole formation, but it is evident that considerably more stoping has been done in the quartz body than in the quartz-haematite portion of the lode. Official returns show a return only of 14 tons crushed for 11.97 ounces of fine gold.

Table showing the Yield of the Marionette.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	ozs.
1912	Marionette, 1848 (2999)	14·00	11·95
	Total	**14·00**	**11·95**

Grace's Mine, G.M.L. 1961.—This mine is situated at a distance of about one mile north of the Marionette.

Fig. 13.



Plan of workings, Grace's mine.

Three shafts* have been sunk on the lease, two to a vertical depth of 80 feet and one 35 feet. The first two are connected by a drive 100 feet in length at the 40 feet level. In this drive two quartz veins were followed; from the north shaft they ran parallel for a considerable distance, but eventually united near the south shaft. When separate their thickness varied from one to six inches, but formed in the south shaft a body of stone the full width of the shaft. The eastern of the two veins was by far the richer in gold contents. The eastern wall consisted of ironstone whilst the western or hanging wall was a rather massive, fine-grained amphibolite.

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* Fig. 18.

A crosscut from the north shaft at the 55ft. level intersected ironstone and quartz leaders for a distance of 40 feet.

From the south shaft a crosscut east from the bottom of the shaft 15 feet in length passed through "blocky" hard fine-grained greenstone. A small quantity of galena was broken from the reef in this shaft at the 40ft. level.

The western shaft has been sunk to a vertical depth of 35 feet and a crosscut put in eastwards a distance of 40 feet. In this crosscut are numerous small quartz veins which carry traces of gold. Twenty-five tons of ore crushed from the workings at the 40ft. level produced by battery treatment 17½dwts. of gold per ton.

One or two quartz veins were being opened out on leases between the Marionette and the Trig. Station HK 48. They are excellent examples of the laterial quartz veins found so often associated with the quartz-haematite schists.

Since my last visit Messrs. Hefferman & Cox, on the Star of Ennuin G.M.L. 2803, have crushed ore from one of these veins, the official record being 118.16 tons of ore treated for a return of 342.89 ounces fine gold. As has already been pointed out, some of these quartz veins produce extensively high-grade ore of which the above is another example.

Table showing the Yield of the Star of Ennuin Reef.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	ozs.
1915	Star of Ennuin, 2803	45·50	125·93
1916	Do.	72·66	216·96
	Total	**118·16**	**342·89**

Marie's Find.—A little work was in progress here on some very small quartz veins associated with the quartz-haematite schists. The workings were in no instance carried to an appreciable depth below the surface.

Marie's Find mine itself was flooded on both occasions when visited, and an inspection was therefore impossible.

Table showing the Yield of the Marie's Find Reef, 2389 ; New Marie's Find, 2389, 2390.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	ozs.
1912	Marie's Find, 2389	252·00	317·66
1913	Do.	40·00	57·16
1914	Do.	44·00	85·69
1915	Do.	..	..
1916	New Marie's Find G.Ms., 2389 N.L. 2390	226·00	144·35
	Total	**562·00**	**604·86**

XI.--WESTONIA GROUP OF MINES.

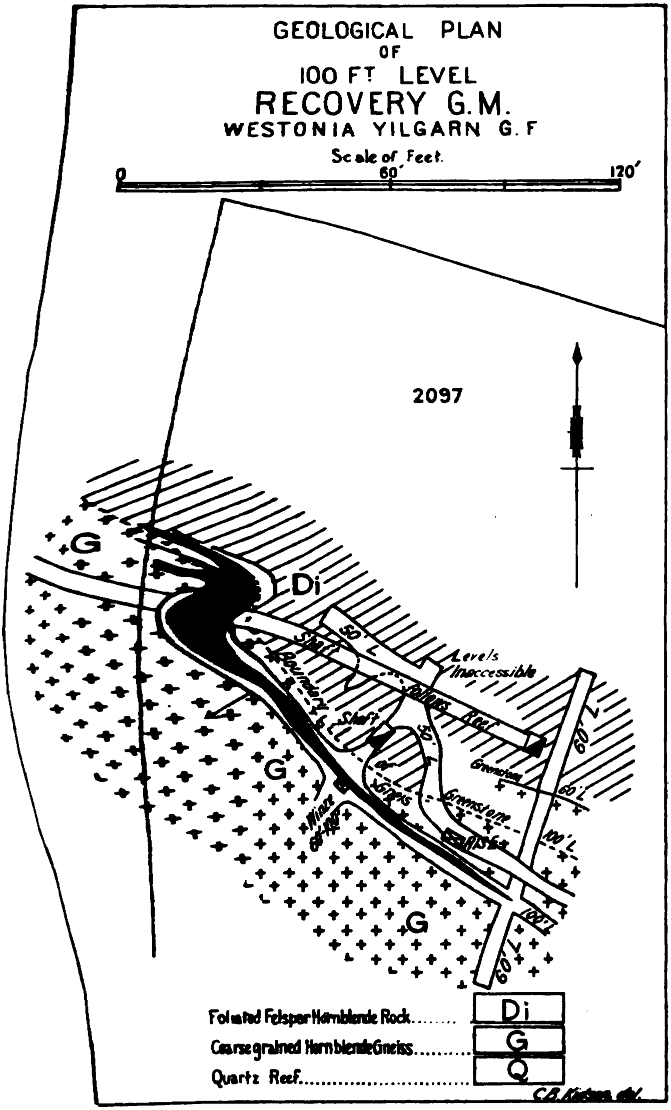
The principal mines of the Westonia group proper are confined within the limits of the Edna May gneissic belt. Outside of these boundaries no lode of any appreciable size or gold contents has been found. In the immediate vicinity of this limited area, especially on the north, south, and eastern boundaries, a considerable amount of prospecting has been done, at shallow levels certainly, but deep enough to intersect any lodes which are likely to exist. Up to the present this development tends, therefore, to prove that outside the gneissic belt it is improbable that extensive or payable lodes will be discovered. Veins of quartz have been intersected, but with unfavourable results, both as regards size and gold values. There is no apparent reason why this should be except that the chief gold-bearing lodes are pegmatitic in origin and have not extended beyond the gneiss, the pegmatites in the greenstone areas belonging to a different age and, possibly, not derived from the same magma.

High gold values were certainly found in the Recovery lode but not for any great length in the reef. Small veins have also been located and worked successfully in the greenstone by the prospectors, but such have invariably been proved to be erratic and small. There is no reason, however, why a repetition of the gneissic belt should not exist on the low-lying ground to the east of the main belt but, owing to the surface being covered up by a considerable overburden, it would be impossible to form any but the vaguest idea where to search for such an occurrence. However, the likelihood should be noted and any loose floaters or rock examined in case fragments came to the surface which would indicate the existence of another covered up gneissic belt.

The mines of the gneissic belt have been described in detail. Not so all the surrounding leases whose workings are in the decomposed greenstones, and do not exhibit any data which would be worthy of record.

Recovery Gold Mine, G.M.Ls. 2087, 2088. (Greenfinch Prop. N.L. G.M.)

Fig. 14.



Geological plan of workings, Recovery Gold Mine.

Location.—The Recovery gold mine lies some short distance north of the main Edna May group.

Geology.—Attention has been drawn to the geology of the country rock under the heading of greenstones. The main lode in the lease lies in the coarse hornblende gneiss which is bordered by a much finer foliated hornblende felspar rock.*

With the exception of the main reef, the leaders or quartz veins worked in this band, though of fairly high gold contents, were too small to yield much tonnage. The main lode has been followed to a vertical depth of 100 feet by an underlay shaft. All the stone from this level to the surface has been stoped. A section of the reef is shown in Fig. 14. Most of the gold shown in the returns was obtained from the wide portion of the reef, the legs not only being smaller but also contained considerably less gold.

Sulphides showed in the stone in the bottom of the level.

The underlay shaft has been sunk some few feet below the 100ft. level but was full of water on date of inspection.

Table showing the Yield of the (Greenfinch Prop.), Recovery Gold Mine.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		Tons.	Ozs.
1911	Greenfinch Proprietary G.M., N.L. .. 2086, 2087, 2088, 2635	472·00	478·93
1912	Do.	3,450·00	1,547·93
1913	Do.	2,878·00	585·82
1914	Do.	776·00	171·05
1915	Do.	240·00	43·30
1916	Do.	59·00	26·92
	Total	**7,875·00**	**2,853·95**

Myrtle Consols South (*Edna May Deeps Mine*) *G.M.Ls.* 2238, 2168, *etc.*

Situation.—The lease is located to the north of the Edna May gold mine.

Geology.—Three distinct classes of rock are found in the mine—the Edna May gneiss and the greenstones surrounding this belt, through which pass narrow granitic dykes, the offshoots of the massive granite. In addition to the above, basic dykes, probably directly connected with the encasing greenstones, occur.

The nature of these various forms of rock types have already been discussed.

The principal mine workings are as follows:—†

1. Main Shaft in south-east corner of lease 2238.

The vertical depth of this shaft is approximately 500 feet A short crosscut was started at the 240 feet level, but discontinued.

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* Fig. 14.
† Plate XIV.

A main drive has been opened out at the 485 feet level on the Edna May lode. The direction of this drive and width of ore body as far as has been exploited, may be seen on Plate 15.

In the description of the Edna May mine, reference has been made to certain basic dykes. One of these plays an important factor in the limitations of the south-west end of the Edna May lode. In the "Deeps," the same conditions exist, for though the basic dyke A is not clearly distinguishable at the end of the lode in the "Deeps" ground, there is every reason to believe it will be found on further development in the south-western end of the mine. The tongue of greenstone found in the 385 feet level in Edna May ground on the footwall of the lode is clearly seen (on the footwall of the lode) in a corresponding portion in the 485 feet level in "Deeps." A winze connecting the shaft to the 485 feet level follows this greenstone. In it are seen numerous quartz veins of a lenticular nature, which were at first taken locally for a south-western continuation of the main lode, but which, in the writer's opinion, are distinct from the main ore body. It appears to be highly probable that a south-western extension of the main lode will, therefore, not be found. There is, however, or should be, a considerable area of gneissic rock still south-west of the main shaft for, in the deep bore, the greenstone was not intersected until a vertical depth of 427 feet was reached. Such being the case,[*] there is a possibility of exploiting payable quartz veins in this direction.

The various granite dykes and quartz veins which were intersected in sinking the shaft, have been plotted on the sections, and further reference is unnecessary here, as they have already been fully described in the previous pages of the present report.[‡]

Water.—Owing to the presence of heavy underground water in certain zones, considerable difficulty was experienced in sinking this shaft. The first water met with was undoubtedly due to surface water soaking through and accumulating in the decomposed country rock and surface beds. These conditions prevailed from the natural water level, 75 feet, to a depth of 200 feet. The flow of water between these levels was not abnormally heavy, but made shaft sinking difficult, more particularly on account of the saturated nature of the rock, which was soft and spongy. Very heavy underground water was first struck in the depressed bore in the 236 feet level, but accurate details of this flow are not obtainable.

At varying intervals in the shaft, flows of water were struck but were held back by filling the water channels with cement pumped in under pressure.[†]

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[*] This does not allow for bore deflection, about which there has been much local controversy. For position of bore see Plate XXI.

[†] Particulars given on page 47.

[‡] Particulars given on page 64.

The most serious of these flows occurred at the 423 feet level. After this one had been cemented back, a seam of cement in the sides of the shaft could be seen at least one inch wide, dipping slightly to the south-east.

From the evidence collected, it seems almost certain that the presence of these various water zones is due to the horizontal fissuring of the gneiss. Sometimes these fissures have been filled with dyke material, sometimes they occur as open cracks. The prevailing dip of both dykes and fissures is to the south or south-west, therefore, they should link up with the main fault plane, described when dealing with the faults and dykes in the Edna May. Further evidence of the horizontal fissuring is evidenced in the Edna May lode itself, and the dykes which have been traced through the various levels in the Edna May and Central mines. On the other hand, at times dykes are found which do not conform with this rule, but having a steeper angle of dip, and consequently cross the horizontal channels. Such form natural independent water reservoirs, the best example of which is the one which was intersected at the 300 feet level in the Edna May. If the water question be considered under the following headings, it should be easily grasped:—

(1.) A main fissured, partly open channel, running parallel to the junction of the Edna May gneiss and greenstone on the footwall or southern side of the gneiss.

(2.) More or less horizontal fissures, open or filled with dyke material, connecting to the first zone and acting as feeders into the same, and finally dykes, which cross the first two zones and thereby divide the water system up, forming underground water reservoirs. The reasons for drawing these conclusions may be more readily followed by perusing the sections on Plate XV.

Unfortunately, complete and accurate data of the pressures and flows encountered was not recorded, though there is little doubt that the pressures correspond more or less closely with the hydrostatic head. Furthermore, it is evident that continual pumping is lessening the underground water-flow, and has lowered the natural water level considerably.

No. 5 Shaft.—Vertical depth 76 feet. Crosscuts extend 70 feet north 20 degrees east, and 80 feet south 20 degrees west from bottom of shaft.

In the northern crosscut, 30 feet from shaft, a small quartz leader and several smaller veins of quartz have been followed for a distance of eight feet west and 12 feet east. The general strike of these leaders is N. 20deg. west and south 20deg. east with a dip to the north-east. The country rock in the north crosscut is gneissic granite. In the eastern drive off north crosscut, a granite dyke is seen in the face, but is not pierced.

In the northern end of crosscut another dyke is seen. This dyke is flat and dips slightly to the south, as it is seen passing out of the bottom of the south crosscut at a distance of 40 feet south of the shaft.

The strike is apparently north-west south-east, with a slight underlie to the south-west; its thickness is about four feet.

In the south crosscut the country rock is also gneissic granite. In both crosscuts small quartz veinlets are common. In the south crosscut there is rather a marked distinction in the colouration of the gneiss. The first half starting from the shaft is dark and perfectly banded, whereas the latter half, though gneissic in structure, is yellow, due to the greater portion of muscovite mica as compared with biotite.

Twelve feet above the level are two small stopes on the side of shaft, strike about north 40° west. The amount of stone taken out of the small reef here is about eight or ten tons.

Gold values and reef cut out in the north end owing to the intersection of a small granite dyke some two feet thick. This dyke underlies to the west at an unknown angle.

Shafts 3 and 4.

In the first place the shafts are connected at the 36ft. level, and a drive extended north-east a further 70 feet past No. 3 shaft.

Thirty feet north-east from No. 3 shaft the contact of the greenstone and gneiss is clearly seen.

From this junction south to No. 4 shaft the rock is gneissic granite, highly decomposed and containing innumerable quartz veinlets which persistently underlie to the north-east.

The strike of these veins varies from north 50° to north 80° west.

From No. 4 shaft a drive extends some 180 feet south-west at the 51ft. level (vertical). In this distance 136 feet is in gneissic rock, when the change to much weathered greenstone takes place.

At a distance of 72 feet from the shaft a reef, four inches wide, was cut and driven on for short distances east and west. This reef dips to the north and strikes approximately east and west. Small quantities of wolfram were found in this reef. Thirty-six feet further south in the crosscut another quartz vein was cut, striking west 50° north and dipping to the north-east.

Another level has been opened out at the vertical depth of 77 feet in this shaft, and a short one at the 83 feet. The first one extends southward a distance of 121 feet, the latter 50 feet northward. In the south drive the greenstone is intersected at the end of the drive. Sixty-two feet from the shaft, the reef seen in the 50ft. level (72 feet from the shaft) is intersected. Here it is four feet wide, but dwindles out in the east drive, which follows its course a distance of some 50 feet. Small quantities of wolfram are found in this lode.

Forty feet south of shaft a vein striking north 70° west and underlying north-east, has been driven on for a distance of 18 feet west. This vein is 18 inches thick in the crosscut, but diminishes to one of eight inches in the drive.

A small dyke of coarse pegmatite, striking east and west through the shaft just above the level, disappears under this crosscut. Another dyke, with similar dip and strike, is seen in the north face of the north crosscut at the 83ft. level. This dyke, which has a thickness of 24 inches, rises from floor of crosscut up to the north face; it is practically horizontal. The level has a length of 54 feet only. At a distance of 35 feet from the shaft two short drives have been put in from this crosscut on a broken vein of quartz, which strikes in the direction of the drives and underlies to the north-east. A considerable amount of wulfenite is present in this vein.

There is little to see in shaft No. 2 as the drives are for the most part filled in. The shaft has a vertical depth of 77 feet, with two east and west drives of 60 feet east and 70 west, connected at the bottom by a short crosscut. From the 40 feet to the bottom of the shaft a coarse granite dyke is the rock passed through. The footwall of this dyke can be seen in the crosscut.* The western drive was filled in and inaccessible. A large quartz vein may be seen in the eastern drive. This is said to be 13 feet in thickness, but the walls were not discernible owing to the ground having fallen in. It appears as if this quartz is striking at a slight angle across the planes of foliation of the gneiss, but such cannot be definitely stated until further work be done. If such be the case it is certainly worthy of extensive exploitation.

Table showing the Yield of the Myrtle Consols South (Edna May Deeps).

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		Tons.	Ozs.
1912	Myrtle Consols leases 2168, 2238 ..	41·00	22·81
1913	Do.	71·00	35·22
1914	Do.	..	..
1915	Do.	..	..
1916	Do.	1,140·00	1,146·32
	Total	**1,252·00**	**1,204·35**

Edna May Gold Mine G.M.L. 2180:

History.—An application for the right to mine on G.M.L. 2180 was lodged by J. Annear and party on 20th December, 1910. The first returns came from that portion of the lode lying near the eastern boundary of the lease, and were, therefore, not sensational. It was not until the present company opened up the 73ft. level for

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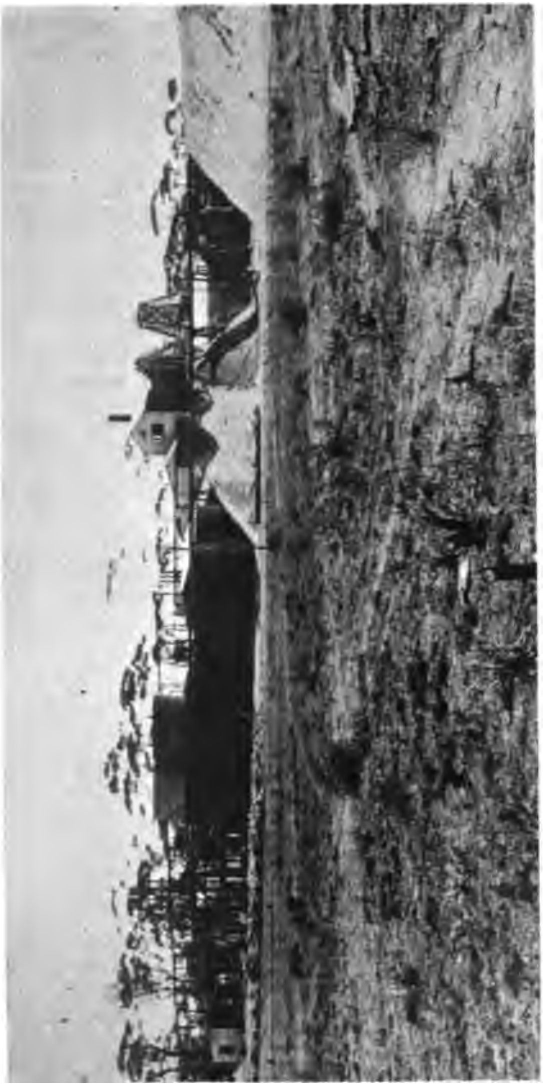
* Plate XIV.

Fig. 15.



General view Edna May Gold Mine.

Photo: T. Blatchford.

Neg. 1309.

a length of over 200 feet in ounce ore that serious attention was drawn to the value of this mine. This development occurred in 1913.

Geology.—The Edna May lodes lie in the rock known as the Edna May gneiss (granitic), though the major portion of the lease is in the foliated hornblende felspar rock and hornblendite, both of which will be referred to as greenstones.

A considerable amount of prospecting has been done by boring and shallow mine workings in the greenstone areas without success. No values of any importance have been found on the lease outside the gneissic area. The greenstones and gneissic rock have already been described.

Dykes.—In the gneissic area several basic dykes occur which can be traced throughout the mine workings.

Dyke A.—It is evident in section (C-D)* that the south-western end of the main lode pitches to the north-east. The evident cause of this is—

(1.) That the gneiss was sheared at right angles to the main lode channel, that is, approximately parallel to the contact of the gneiss and greenstones.

(2.) That the main lode channel did not extend past this series of shear planes which, in consequence, mark the south-western termination of the lode.

(3.) That as these cross shear planes dip to the north-east the end of the lode has a corresponding dip.

The massive greenstone does not actually form a footwall to the end of the lode.

The dip of the cross shear planes varies, hence we find a different pitch for the end of the lode between the 150ft. level and the surface to that between the 225ft. and 485ft. levels (Deeps).

The shear plane from the 225ft. downwards has been subsequently opened and filled with dyke material (Dyke A),* and this fault plane can, in consequence, be easily traced in the mine workings. That this dyke is of later age than the lode is evidenced by the presence of fragments of the lode quartz in the dyke.

Dyke (B), which is an extremely decomposed one, is first seen at the back of the 73ft. level, and passes through the main lode in which it has been traced to the south winze between the 225ft. to the 300ft. level; after this being reached, it is not seen again.

Dyke (C).—This dyke is found in the Edna May Deeps shaft at 344 feet, and probably in the Edna May Central main shaft at 295 feet. It should occur somewhere not far above the 385ft. level in the Edna May mine. This dyke apparently dips west to south-west at a small angle from the horizontal. Both B and C dykes are important from a mining point of view.

Throughout the mines in the gneissic area are numerous granitic dykes which cut through all the other rocks. These are important factors in the mining operations for several reasons, the chief of which are: (1) They deplete the stopes of the ore in the direct ratio of their thickness. (2) The lodes, when faulted, usually fault along them invariably as overthrust faults, and (3) They act as water carriers or bank the water up forming thereby, at times, extensive reservoirs. which have considerably hampered mining operations.*

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* Plate XV.

The thickness of these dykes varies considerably, from two to three inches to 20 or more feet.

As a prevailing rule they dip to the south-west and have a tendency to get smaller as they proceed north-east, thereby showing that the intrusions have emanated from the granite on the south or west side of the belt.

Before leaving the subject of dykes reference must be made to the greenstone found on the footwall side of the No. 2 Edna May lode. At the 73ft. level this greenstone was intersected but not passed through by a crosscut from the No. 2 reef. The main crosscut at the 150ft. level also revealed the occurrence of greenstone in a corresponding position but not its thickness.

In the depressed bore in Edna May from the 300ft. level the bore ended in greenstone. It was not until the boring for the lode in "Deeps" by a depressed bore was completed that any light was thrown as to the extent of this greenstone belt. This bore, after passing through the lode, passed through eight feet of greenstone on into gneissic rock. Sections cut of the basic rock at the above intersections tend to a general classification of all the samples as one rock. The inference is then, that a tongue or dyke of greenstone forms a footwall for the No. 2 lode. No. 2 lode joins the main lode just above the 300ft. level, and as greenstone of a similar nature as the suggested dyke forms the footwall of the main lode at 455ft. level in "Deeps," and also in the depressed bore in "Deeps," it follows that this assumed dyke or tongue forms the footwall of the main lode from somewhere near the 300ft. level downwards. This will probably account for the slight narrowing of the lode in "Deeps," but whether the narrowing continues upwards to the 300ft. level in Edna May is not yet known, though it appears highly probable it will.

Lodes.—In the Edna May lease there is one main lode and several smaller veins, the most important of which are known as the Footwall or No. 2 reef, and the hanging-wall reef. The main body, as seen on Plate 15, strikes perceptibly across the planes of foliation in the southern portion, but gradually turns round to a more or less east and west course and follows the planes of foliation of gneiss just after the lode crosses the eastern boundary of the lease; without doubt the richer portion of the lode is the first. From the surface to the 200ft. level there is an extension of the main lode in an easterly direction along the shear plane extending from this level to the surface already referred to. This portion underlies north by east, whilst the other portion of the lode has an underlie varying from west by north to north by west.

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* A full description of the nature of the above rocks is to be found in the pages of the present report, and the petrological descriptions in Section D.

It will be seen that the smaller veins have a prevailing strike approximately to east and west with a persistent underlie to the north, or, in other words, they follow the planes of foliation and do not, as the main lode does in the southern portion, cut across the combs of the gneiss. In several instances such veins are found to be joined to the main ore bodies, and may therefore be considered as offshoots or laterals of the latter.

On the other hand, there are numerous smaller veins whose origin is doubtful. These have no direct connection apparently with the main ore bodies. As far as can be seen their origin is different and they will probably be found to be merely quartz fillings from siliceous-bearing waters of foreign origin, or segregation products of the gneiss itself. So far they have been proved to be, comparatively speaking, non-auriferous, certainly they are not payable veins under existing conditions. Their number, however, is legion, and in certain portions of the gneiss would form an appreciable proportion of the whole rock.

A good example of this form of quartz vein is to be seen in the north crosscut from the 73ft. level in the Edna May Central. The main lodes are interesting in that, though they represent a form of occurrence commonly found in the Eastern Goldfields, yet, as a rule such have not proved to be gold producers of a payable nature.

The Main Lodes.—In the upper levels of the Edna May the main lode had several characteristics which made it appear as if the formation was due to ordinary replacement of a partially closed fissure. Throughout the quartz were remnants of the walls, and the colour and texture of the quartz itself seemed to be variable at different points. Owing to the crushed nature of the lode and the form of mining adopted, investigation was difficult. It may be noted here that seldom, if ever, could more than a small section of the lode be seen at one time owing to the fact that it was fractured horizontally and, in consequence, it was necessary to stope in sections, the roofs of the sections being held up by "false" sets and head boards. However, in the lower levels, conditions for investigation were more favourable, and the rock forms being undecomposed gave more satisfactory and conclusive results.

Petrological examinations of typical samples of the lode taken between the oxidised zone show that the quartz is of a granitic character. Rows of fluid inclusions are constantly present. Felspar is almost invariably present and constantly associated with the quartz plates, being either contained in or containing this mineral, thereby proving a more or less contemporaneous solidification of the two. Throughout the lode wolfram is of common occurrence especially on the footwall side. This mineral usually occurs in bunches, but sometimes in elongated flat lenses on the footwall. Galena is found sometimes in fine grains or crystals, at others in bunches. Wulfenite* and crocoite† are occasionally found, more particularly where the quartz is at all inclined to be vughy. In the oxidised zone scheelite was said to be present and concentrating tables were used to recover this mineral: unfortunately samples of the concentrate were not procurable, and there is some doubt as to whether the supposed scheelite was not really wulfenite. Molybdenite is not at all infrequent and is found not only in the lode itself but also in the gneiss. Pyrites and marcasite are found in bunches and minute specks scattered irregularly throughout both lodes and walls. All the metallic minerals taken together, however, form a very small percentage of the whole, and concentration was found to be unprofitable and in consequence was not continued.

In the upper levels the quartz was variable in general appearance, being sometimes a milky white, sometimes clear and glassy, and at others glassy but either coloured brown or yellow. As a general rule traces of kaolin were found throughout. On account of the fractured nature of the quartz, the presence of the kaolin appeared to be due more likely to the filtering of the mineral into the cracks than the decomposition of an original felspar. In the unaltered zone, however, felspar is readily seen throughout the stone, more particularly in the southern end, where the pegmatite structure is very evident: in fact at times, the lode resembles coarse-grained granite more than anything else.

From the above evidence there seems to be no reason to doubt that the nature of the lode is granitic, and that it represents the acid residuum of a quartz felspar pegmatite.

The occurrence of such lodes is frequent, but the high gold contents such as the Edna May lode possesses is unique for Western Australian mining.

In the Southern Cross area numerous similar lodes occur, but the gold contained does not amount to any appreciable quantity. Molybdenite is frequently found in small quantities associated with this class of lode throughout that area. One striking feature in the gold occurrence in the Edna May series of lodes is, that where the lode crosses the planes of foliation of the gneiss, there it is that the high gold values occur, whereas when the lode is found running parallel with the planes of foliation the gold values are invariably low and inclined to be erratic.

Naturally the laterals, if this rule holds, will be found to be low-grade and patchy. It is well known that the mineral distribution in pegmatites, or any dykes of granitic character, is usually, if not invariably, irregular.

In the Edna May lode the highest values are found at the extreme southern end of the lode in the two lower levels, and in the 75ft. and 100ft. levels at the southern bend. These values, though not quite so high, extend along the lode to where it forms a big bulge, when they diminish materially, becoming again perceptibly less a short distance after this bulge is passed to the eastward.

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* Tungstiferous molybdate of lead.
† Chromate of lead.

The gold is disseminated throughout the quartz as a rule in the finest of patches, very coarse gold being a more or less rare occurrence in any part of the mine.* It is found in close association at times with the wolfram, molybdenite and wulfenite, more particularly the first material. In one or two instances gold was found well embedded in felspar crystals, and in the wolfram.

There is no evidence of any extensive secondary segregation of the gold in the lode; what data there is rather points to the conclusion that the gold was formed contemporaneously with the lode material.

It is difficult to fix a vertical depth for a sulphide zone as there is no definite line between oxidised and sulphide ore.

Galena was obtained from the back of No. 1 stope in the 225ft. level, *i.e.*, a vertical depth from the surface of 208 feet. Certainly oxidation did not reach the 225ft. level. On the other hand, as the lode is traversed eastward the sulphide zone seems to be rising but, nevertheless, is irregular.

The natural water level of the gneiss was originally about 75 feet. Below this, to a depth of about 200 feet or more, the drainage from the weathered portion of the gneiss was comparatively heavy. This was undoubtedly due to the weathered rock being saturated from surface soakage which, on continuous pumping, was eventually drained.

A far greater volume of water than the above was encountered in the main crosscut at the 300ft. level, the first water pressures in the drill holes showing 82lbs. to the square inch. Even when pumping a volume of 60,000 gallons† per hour, the pressure did not fall below 30lbs. to the square inch for some considerable time.

It has already been noted that the eastern extremity of the lode ends at a shear plane which strikes approximately east and west and dips to the north. Also that most of the granite dykes dip at varying, but low angles to the west or south-west, and are continuous through the lode and various rock formations. When the crosscut at the 300ft. level was opened up it was found that the water was confined behind one of these granite dykes, and that the country was heavily charged with water from this point, which was 40 feet on the footwall side of the shear plane above referred to, and the water zone extended for a further distance of 40 feet on the hanging wall side of the lode.

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* Coarser gold has been since found in the "Deeps" **and 385ft. level, Edna May**

† According to estimate of management.

The evidence seems conclusive that this is the main water zone in the mine and is partly supplied by water permeating along the dyke channels, but probably the main supply is from parallel open fissures or cracks, such as have been cut in the "Deeps" main shaft. Furthermore, it is evident that the granite dykes have cut this water zone up into sections, the water of each section being more or less isolated from the other.

Owing to the irregularity in occurrence of both the dykes and open water channels, it is impossible to supply accurate plans or sections of their position or extent, but the above data should be of use in mining operations, the obvious course being to keep bore holes well beyond the working faces and be always prepared for heavy flows of water, especially when piercing one of the dykes.

Faulting.—With the exception of a small fault above the 225ft. level, there is no evidence of faulting in the mine. In the exception cited above, the changing wall lode has been overthrust on a granite dyke a distance of some nine feet.* This fault will probably be found extending through the other lodes. A similar faulting is found at about the same level in the Central mine, but whether the two are connected has not been proved. There is certainly a strong probability of such being the case, as both faults are approximately horizontal with a throw in the same direction.

Table showing the Yield of the Edna May.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	ozs.
1912	Edna May, 2180	581·00	919·27
1913	Edna May G.M. Co., N.L., 2180, 2605	9,119·00	8,975·21
1914	Do.	28,998·00	28,755·69
1915	Do.	35,743·00	35,468·83
1916	Do.	36,623·00	36,821·40
	Total	**111,064·00**	**110,940·40**

Myrtle Central (Edna May Central) Mine, G.M.Ls. 2291, 2585, 2615.

History.—The Myrtle Central lease 2291 was applied for by F. Hanks and party on 10th February, 1911. From hearsay evidence, it appears that gold was discovered on this lease shortly after the Recovery lode was found. The first crushings obtained were not high-grade, but led to the development of the rich portion of the lode in the adjoining Edna May lease. The lease was held under option by the Edna May company during part of the year 1913, but the option was not executed. Shortly afterwards a company was formed under the name of the Edna May Central, and included leases 2585, 2615.

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* *Vide* Section, Plate XV.

The mine was soon equipped with a ten-head stamp mill which has run continuously since. During the development of the main lode a deposit of gold-bearing alluvial was discovered overlying the eastern portion of the lode. Ore won from this deposit enabled the mine to continue working and, furthermore, led to the discovery of a second lode which is now the mainstay of the company. This discovery was made in December, 1915.

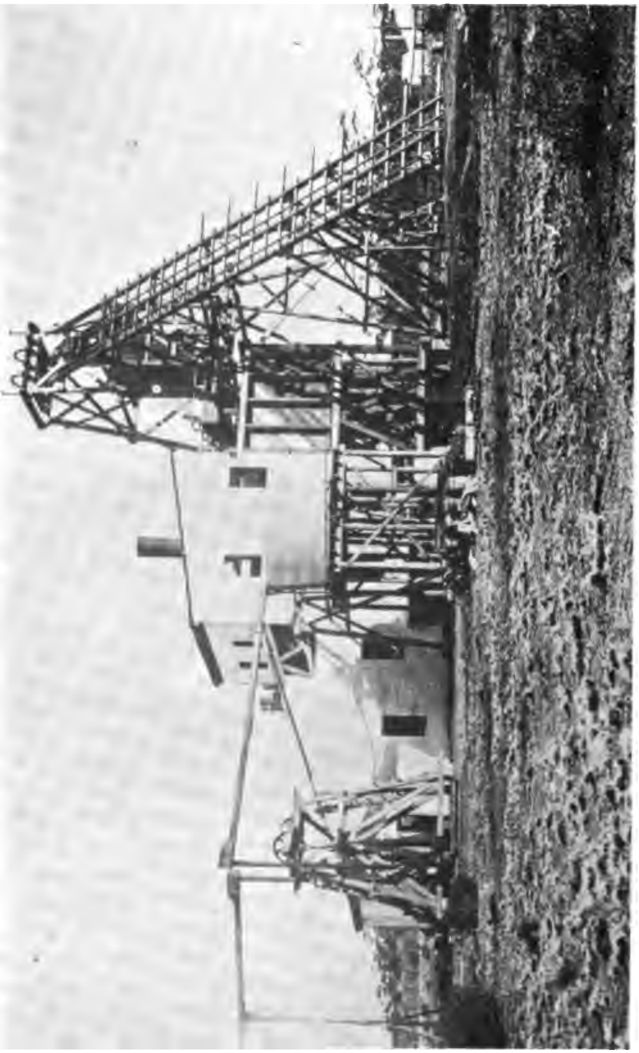


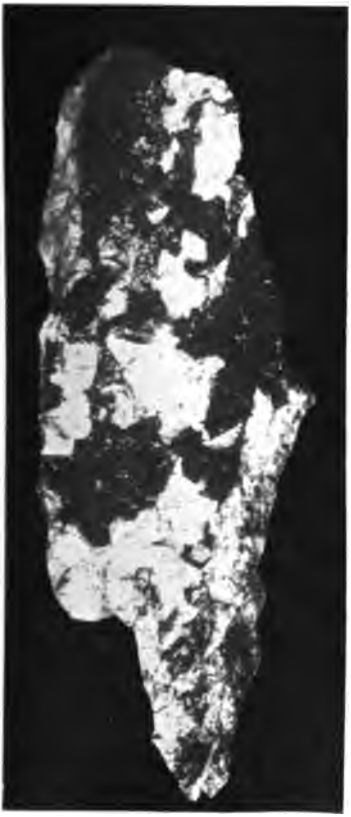
Fig. 16.

Photo: T. Blatchford. **General view Myrtle Central Battery.** Neg. 1307.

During the early part of the year 1916, owing to the publication of phenomenally high assay values from this lode, the shares rose far beyond their intrinsic value. As the crushing returns did not respond to these values there was the inevitable slump in the market, with the usual result.

Geology.—The whole surface of the three leases is covered with superficial deposits of varying thickness. The geology is best studied by examining the 73ft. level which has been extensively exposed by numerous mine workings.* At this level the major portion of lease 2291 is found to be in gneissic rock, the southern portion and the north-east being in greenstone.

Fig. 17.



Neg. 1492.

Photo: R. H. Irwin.

Molybdenite in quartz, Myrtle Central Gold Mine.

As the gneiss underlies north it should pass under the greenstones in leases 2585 and 2615 at no great depth.

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* Plates XIV. and XV.

The general features of the greenstones and gneiss have already been discussed.

Dykes.—The granite dykes are similar in every respect to those in the Edna May, and, in some instances, are continuations of the same.

Only one basic dyke has been intersected in the mine, which is probably the dyke C* found in the "Deeps" shaft and Duff's bore. This dyke was intersected in the main underlying shaft at the 295ft. level.

Lodes.—There are two main lodes in the property: one the continuation of the Edna May line; the other, known as the "new" lode, a replica in many respects of number one. Both have been mined to a vertical depth of 225 feet.

Edna May Lode.—After passing into Central ground, this lode lost its gold values to a considerable extent. It also became smaller, lenticular, and more irregular in habit. Apart from these features, the general geological characteristics are similar. Wolfram and molybdenite have both been found in isolated patches in this portion of the main lode.*

Edna May Central New Lode.—In the latter part of the year 1915, whilst working an alluvial deposit, a large body of quartz was cut by the merest chance. On development, this quartz proved to be a body of stone similar in many characteristics to the main lode. As a matter of fact, the two lodes appear to be directly connected by the No. 2 (Edna May), No. 3 (Central) reef. A plan of the 73ft. level workings show a marked parallelism of the two bodies. Further, the reversal of dip in the south-eastern end is common to both. Both lodes, when crossing the plane of foliation, bulge, and the gold values, though not proportional, yet are higher in each at the bends than elsewhere.

The distribution of the gold in the quartz is similar, and there is even a strong resemblance in the quartz itself.

The occurrence of felspar and the characteristic pegmatitic minerals, however, are not so pronounced; neither were they in the upper levels in the Edna May lode. The new lode seems particularly free from base minerals, a small amount of iron sulphides and galena being the only ones visible. The hanging wall "leg" is different in form to an ordinary lateral, but is comparable with the hanging wall reef of the main lode.

Geologically, the chief difference in the two is that the south-western end abuts on the greenstone proper and does not end on a shear plane as in the main lode.

A very interesting mining as well as geological problem arises as to what will happen to these lodes at depth, and as this subject concerns the Central mine more closely than the others, it may be as well to discuss it here.

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* Fig. 17.

The data gained from the present survey point to the following conclusions:—

(1) That the lodes are of pegmatitic origin, and as they have no extensions beyond the gneissic belt they must necessarily have come from a deep-seated magma. Their permanency at depth should therefore be assured, though, of course, the size of the veins or their mineral contents is still a matter of conjecture.

(2) At the 73ft. level there seems no doubt that the system of main lodes at least is a connected one. The hanging wall reef in the Edna May, the footwall reef, Edna May, or No. 3 in Central, undoubtedly connect, as also does the hanging wall leg of the Central new reef.

(3) As the footwall reef in the Edna May gradually inclined towards the main lode and eventually connected with it above the 300ft. level, so the new reef is gradually approaching the main lode, and, furthermore, it must be noted that the west end of the main lode is also moving towards the west end of the new reef. Under normal conditions this intersection should take place in "Deeps" ground at some 700 to 800 feet, the major portion of the reef being in the deep blocks of Central ground.

The whole system of quartz reefs in the gneissic belt appear to be converging to a common source, a parent dyke, the extent and mineral contents of which it is impossible to foretell.

To enumerate the details as regards the extent, dip, etc., of the various quartz reefs and lenses in the mine is unnecessary, as they are produced on the accompanying plans drawn to scale.

East of the main underlay shaft and just above the 73ft. level an alluvial deposit was intersected which was distinctly auriferous. The extent to which this deposit has been worked may be seen on plate 15. What the real width is cannot be stated, as only that portion which was considered milling dirt has been taken out. The thickness thus worked varied from about 4 feet 6 inches to 8 feet; the average being between six to seven feet. The deposit consists of sub-angular quartz pebbles and boulders, cemented together with a ferruginous clay. Gold was visible in some of the pebbles, also in the cementing material. At times the pebbles were found with patches of plate gold on the outside, the plates having an area of a halfpenny piece. The strike of the auriferous portion of this deposit is north-east south-west with a gradual dip to the north-east.

The south-west end is apparently striking towards the outcrop of the south-west end of the main lode (Edna May). There seems no doubt that the "lead" has been formed partly from the weathered portions of the main lode and largely from that of the new lode. Specimens of some of the boulders in the south-west end are identical in nature to the stone of the main lode. On the other hand, there is a class of boulder which seems foreign to both of the main lodes, and thereby points to the possibility of a third reef which at present has not been discovered. If such be the case, it should be found north-west of the Edna May main shaft. Probably this block of ground, viz., between the Edna May main shaft and "Deeps" No. 2, will demand more attention in the near future; it certainly warrants prospecting.

The gold is distinctly of two classes—reef and precipitated gold. Some of the pebbles have fine gold scattered throughout them and resemble so closely the main reef stone that it would be impossible to doubt their common origin.

The plate gold round the pebbles and in the cementing material is undoubtedly precipitated gold; such is of common occurrence in the alluvial deposits of Western Australia.

There is no data available whereby the gold won from the different lodes and alluvial can be tabulated separately.

Table showing the Yield of the Myrtle Central (Edna May Central).

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	ozs.
1912	Myrtle Central. 2291	595·00	190·38
1913	Do.	156·00	53·58
1914	Edna May Central G.Ms., N.L. ..	7,029·00	1,446·23
1915	Do. 2291, 2585, 2615	25,027·00	5,424·47
1916	Do.	32,062·00	11,811·79
	Total	**64,869·00**	**19,926·45**

EDNA MAY CONSOLIDATED GOLD MINE, N.L., G.M.Ls. 2570, 2617, and 2644.—This mine now embraces the two following leases: Myrtle East G.M.L. 2570 and Edna May East G.M.L. 2617.

Most of the mining operations have been carried on in the former, the old Myrtle East lease, which joins on the western boundary to the Edna May Central mine.

Five shafts have been sunk on this lease, four varying from a vertical depth of 60 to 75 feet, and one, the main shaft, has reached a level of 210 feet below the surface.

Main Shaft, 210 feet.—This shaft, after passing through overlying superficial deposits of a thickness of some 50 feet, entered the gneissic granite zone and remained in same for a vertical depth of 180 feet, after which it entered the underlying greenstones and remained in the latter rock to the bottom of the shaft.

From the 210ft. level crosscuts were extended north-east 200 feet and south-west 80 feet.

In the north-east crosscut the gneiss was intersected at a distance of 40 feet from the shaft, and the crosscut remained in this ss of rock to the end. A small quartz leader was passed through t a distance of 75 feet from the shaft, the vein having a north-west south-east strike; this vein was followed for some distance o the north-west,* but was of little mining importance as far as e development showed. Further than the intersection of a few ining quartz seams and very small pegmatite veins, the crosscut id not reveal any other feature worthy of notice.

The south-western crosscut is in the typical greenstones described in the previous pages of this report.

In the early stages of the mining the water level was between he 65ft. and 70ft. levels, but was gradually lowered by the drainage from the lower workings of the deeper adjacent mines. The hourly output from the bottom of the shaft was officially given as nder 5,000 gallons.

Shafts numbered 1 to 5 on accompanying plan are of comparatively shallow depth, the maximum being 75 feet.

From No. 1 shaft crosscuts extend north-east and south-west, he former intersecting No. 2 shaft.

In the southern crosscut a band of granitic rock was intersected. This may be a corresponding or the same band to that found in the plat of the 300ft. level in the Edna May mine, but is so weathered here as not to be readily classified. The remainder of the southern crosscut is in highly altered greenstone. The north-eastern crosscut from No. 1 shaft is in soft decomposed greenstone for a distance of 60 feet, beyond which point gneissic granite is the prevailing rock in all the workings.

There is a marked difference in the colouring in the greenstone in this crosscut. For a distance of 30 feet back from the gneiss the rock is of a dark-brown appearance and much iron-stained. From this point to No. 1 shaft the brown is replaced by a pale to dark-green colouration with dark-green or brown bands. A similar rock is found in the north crosscut from No. 4 shaft in the Golden Point G.M.L. 2608, and at about the same distance from the contact of the gneiss and greenstones.

There are strong reasons to suggest that this rock is produced by the decomposition *in situ* of some rock rich in magnesian-bearing minerals, such as a peridotite. The green colouring is due to chromic oxide.

From No. 2 shaft, drives and crosscuts extend north and eventually connect with No. 3 shaft.

In the drive immediately east of the shaft a vein varying in thickness from a few inches to four feet, but yielding payable gold values, has been opened out for some considerable distance. Stoping for a width of from two to three feet has been commenced a short distance north of No. 2 shaft.

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* Plate XIV.

A rise connects the 75ft. levels of No. 5 shaft to the above drive.

As may be readily seen from the accompanying plan, numerous quartz veins have been intersected, some of which contain sufficient gold to go to the battery. Of these, there seems little doubt that the reef worked in No. 4 shaft is the same as the one worked in the 60ft. and 75ft. levels north of No. 5 shaft, and is probably a continuation of the "new reef" in the Edna May Central mine.

Most of the veins run east and west approximately, *i.e.,* parallel with the planes of foliation of the gneiss. It has already been pointed out in the previous pages of this report that such veins are usually lenticular and irregular in both occurrence and gold contents. On the other hand, the vein in the workings to the east of No. 2 shaft strikes across the planes of foliation, and this vein should be worthy of further exploitation. The same applies to a reef being opened out in the winze north of the rise from the 75ft. to the 60ft. levels, and between No. 2 and 5 shafts.

There is also a large area of gneissic rock in the eastern area of lease 2570 still unexploited. This area is well worthy of development on the chance of cutting a similar deposit to the Edna May Central main lode and the Central "new reef."*

Table showing the Yield of the Edna May Consolidated G.M.Ls. 2570, 2617, 2644.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons	ozs.
1916	Edna May Consolidated, 2570, 2617, 2644	668·00	261·16
	Total	**668·00**	**261·16**

Golden Point Gold Mine G.M.L. 2608.

Location.—The Golden Point mine lies to the immediate south of the Consolidated and Edna May Central gold mines.

Geologically it is situated in the main greenstones.

Geology.—In no instance does the country rock outcrop, the whole surface being overlain with a mantle of debris the maximum thickness of which is about 65 to 70 feet.

The country rock is highly weathered foliated greenstone of the prevailing hornblende-felspar type. Possibly the hornblendite extends through the lease in the end of the north crosscut from No. 4 shaft, but the rock is so highly weathered as not to be definitely determinable. Throughout the workings numerous quartz veinlets nd pegmatitic dykes have been cut.

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* Since writing the above a new quartz reef has been cut in a north-west cross-cut from the main north-east cross-cut, which has every appearance of being a similar lode to the "new reef" in the Edna May Central mine, *vide* Plate XIV.

The quartz veins have not proved in any instance to contain ayable gold, neither do they in any instance attain sufficient thickess to be even treated as low-grade mining propositions.

The principal veins are found in shaft No. 6 at the 92ft. level. Here two irregular quartz seams were cut, and the western one ollowed in a drive for a considerable distance. The stone was ollowing the planes of foliation, but was too low-grade for mill reatment and scarcely warranted prospecting at a greater depth. Both veins in their south-eastern end extend into the Edna May Consols, where they maintain the same characteristics.

XII.—BATTLEFIELD CENTRE.

The mines of this centre belong to three distinct classes—

(a.) Reefs occurring in an acid gneiss.
(b.) Reefs occurring in the foliated greenstones.
(c.) Pegmatite dykes of a recent age occurring in the foliated greenstones.

Of the first class there are two examples—the Hill End and Battler-cum-Great Battler. Of these the former has not been developed to any great extent owing to the extremely hard nature f the encasing rock. The reef, however, is well defined and the old contents encouraging.

A fairly long quartz vein has been opened up in the Battler roup for a vertical depth of over 100 feet. In this case, the ncasing gneiss was soft and the mining conditions comparatively ourable. The reef, though extremely narrow, contained fairly igh gold contents. Of the second class there are many examples t, with one exception, the veins are either small and comparaely rich in gold or large and extremely low-grade.

The Pertha M. reef, which belongs to the second class, has en worked to a depth of over 100 feet vertical, and though the ot in the shaft is large and high-grade, it has not been opened ut horizontally, so it is problematical whether the reef will be of fficient length to form a permanent mine.

Of the third class, there are one or two cases in which pegmatite ns, of an age later than the main Edna May lodes, have been ound, carrying free gold, but it is extremely doubtful whether they ill ever be exploited to any extent.

In all three cases the reefs are closely associated with the urrence of granitic dykes, a fact which tends to prove the disurbed nature of the country rock in which they occur.

The following are descriptions of the mines which were open r inspection.

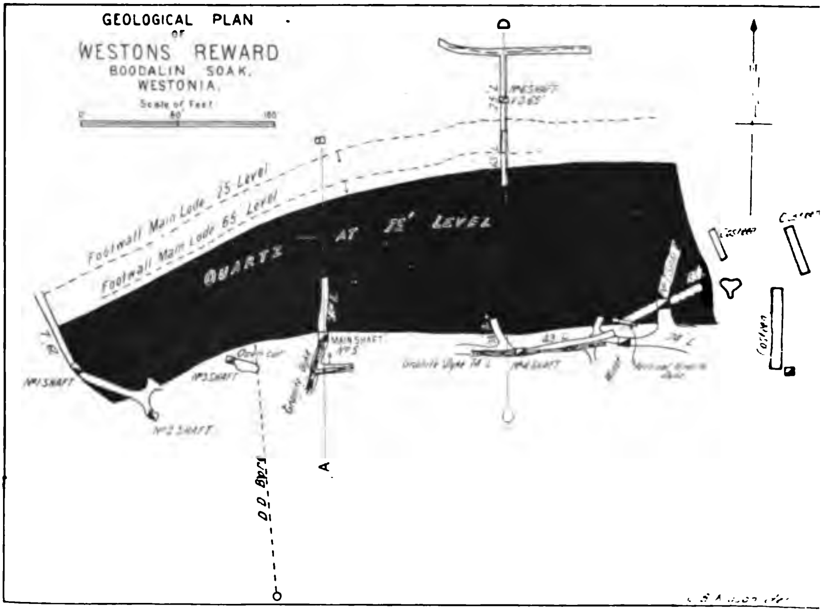
Weston's Reward Gold Mine 2724.—Gold was first discovered the Westonia district by A. D. Weston, his application for a ward Claim being lodged on 20th December, 1910.

The lease, which now bears the discoverer's name, is situated near Boodalin Soak. Geologically, its position is close to the junction of the greenstones and the granites which outcrop in a conspicuous line to the east of the "soak."

On the surface of the lease a rather conspicuous quartz outcrop* is seen striking east and west. The gold was found in the vicinity of this outcrop.

In all, seven shafts have been sunk, and a certain amount of driving and crosscutting done at levels varying in vertical depths from 25 to 75 feet. The extent of these may be seen in Fig. 18 and Fig. 19 which shows the sections across the lode.

Fig. 18.



Geological plan, Weston's Reward Gold Mine.

The reef itself is a large one, being as much as 90 feet across one of its widest portions. In the upper levels, particularly in the eastern end, a considerable amount of iron oxide is mixed with the quartz, but this is soon replaced by sulphides. The amount of gold estimated from bulk samples of the lode proper is low and not payable.

In sinking No. 4 shaft payable gold values were encountered to about the 46ft. level, but these were passed through and missed n the drive at the 73ft. level. However, they were subsequently und and stoped out for a distance of 35 feet east of No. 4 shaft, etween the 73ft. and 46ft. levels. The width of ore broken was

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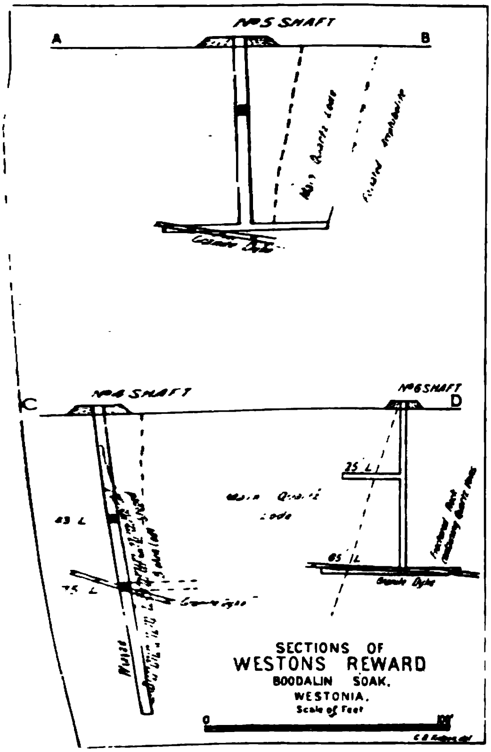
* Figs. 18 and 19.

Fig. 19.



Geological sections, Weston's Reward Gold Mine.

about 20 feet to 24 feet, the tonnage represented being 150 to 170 tons. From the 46ft. level a stope was run 20 feet west and 35 feet east from the shaft, the highest point being 10 feet up from the 46ft. level. The total tonnage from these two stopes was about 200 tons, and gave a return of 28 dwts. total gold per ton. The stone broken consisted of small vein quartz and gangue. It would appear that the gold is a local enrichment in the crushed greenstone forming the hanging wall of the main lode, and does not give the appearance of a permanent ore channel. Shaft 7 was sunk to a vertical depth of 55 feet and then on the underlie to the 73ft. level. Drives were put in 32 feet south-east and 35 feet north-east from the shaft at the 55ft. level.

In the western drive a small pegmatite dyke was cut in which free gold was noticeable.

The rock in these drives is much broken and contains a variable amount of auriferous quartz veins. Immediately under the level is the main quartz body, which has not been prospected at this point.

At a distance of 40 feet west from the bottom of the shaft a winze has been sunk to a depth of 50 feet in the sulphide zone. The country is hard and the veins irregular in size and values.

From the winze to the shaft another stope had been taken out, producing about 80 tons of crushing stone similar in nature to that already referred to. Several pegmatite dykes pass through the workings in the directions indicated on the sections.

From No. 6 shaft, at a depth of 65 feet from the surface, a crosscut has been driven 43 feet south, for the most part in the main lode. In the north crosscut, at a distance of 22 feet from the shaft, broken country containing quartz leaders was driven on east and west for distances of 43 and 30 feet respectively. The gold values were low in these drives. In the drives the country rock, which, like the footwall rock, is a foliated felspar-hornblende gneiss, is much broken and crushed.

Taken as a whole, the workings reveal the presence of a rather large body of quartz on both sides of which the containing rock has been crushed, and in these fissured zones smaller veins of quartz occur which contain payable gold. The main body, so far, has not been proved sufficiently high grade to warrant further development. An attempt was made, by boring, to intersect the main lode at a vertical depth of 500 feet; unfortunately, this bore did not meet with the success anticipated, the site of the bore hole being apparently too far to the west.

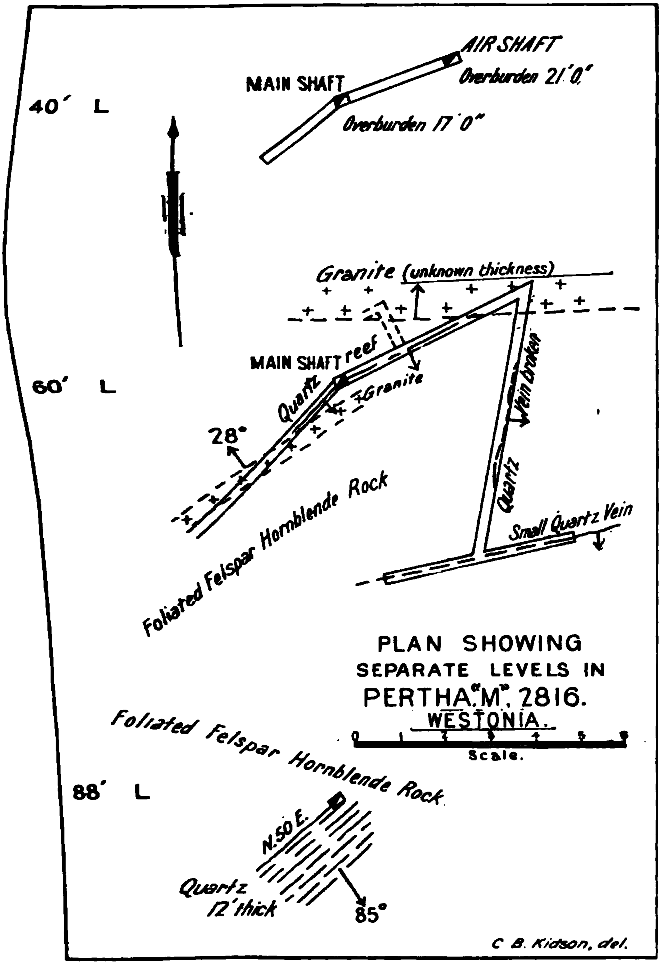
Table showing the Yield of the Weston's Reward.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	ozs.
1915	Weston's Reward, 2724	35·00	57·24
1915	Weston's Reward G.Ms. N.L., 2724, 2761	418·00	384·56
1916	Do.	55·50	40·10
	Total	**508·50**	**481·90**

Pertha M. Gold Mine, G.M.L. 2816.—This mine is situated about 25 chains to the south of Boddalin Soak, and lies almost adjacent to the Lloyd George G.M.L. 2259.

The main workings consist of one shaft sunk to a vertical depth of 88 feet. Further sinking was being carried on with the intention of reaching water level before opening out on the reef again.

Fig. 20.



Geological plan, Pertha M. Gold Mine.

40ft. Level.—At the 40ft. level the reef was followed in a drive starting north 70 degrees east for a distance of 27 feet, and south 51 degrees west at a distance of 21 feet.

Most of the stone from the back of these levels has been taken out up to the over-burden, which, in this particular locality, has a thickness of some 17 to 21 feet. There was still stone of a thickness of four feet showing in the western face. The underlie of the reef is slightly to the south, but for practical purposes the angle is negligible.

60*ft. Level.*—At this level a serious mistake was made in not sinking deeper before opening out on the reef, for as it is, the workings are immediately over a granitic dyke, and though there is a well-defined reef beneath this granite "bar," immediately above it the country is much disturbed and the reef with it.

The extent of the workings at this level may be seen on the accompanying plan.

In the western drive the dyke above referred to has taken possession of the drive. This dyke is comparatively flat, underlying slightly towards the north at an angle approximately 28 degrees from the horizontal. The dyke in the drive has a thickness varying from three to four feet, and passes through the shaft immediately below the level. In the back of the level little, if any, stone can be seen, and what stone there is shows signs of being much broken and mixed with the encasing rock.

In the eastern drive another granite intrusion has been intersected in two places, viz., at the end of the north-eastern drive and at the end of a short crosscut branching from the drive north-westward at a distance of 20 feet from the shaft. This granite may be a tongue of the main mass, but possibly is the western wall of the massive granite outcropping at Boddalin Soak. Certainly the contact cannot be far distant.

In the south crosscut from the end of the eastern drive there is little to be seen. A small quartz vein was followed for some considerable distance, but this soon vanished.

At the end of the crosscut another small vein, carrying gold in appreciable quantities in places only, was followed east and west. This vein dips to the south.

When the mine was last visited the prospectors had opened out the main reef at the bottom of the shaft, the reef here having a width of some 12 feet. A crushing from the stone broken at this spot yielded highly payable gold values. The policy decided on at this time was to continue sinking to water level rather than attempt to open out the reef at such a shallow depth.

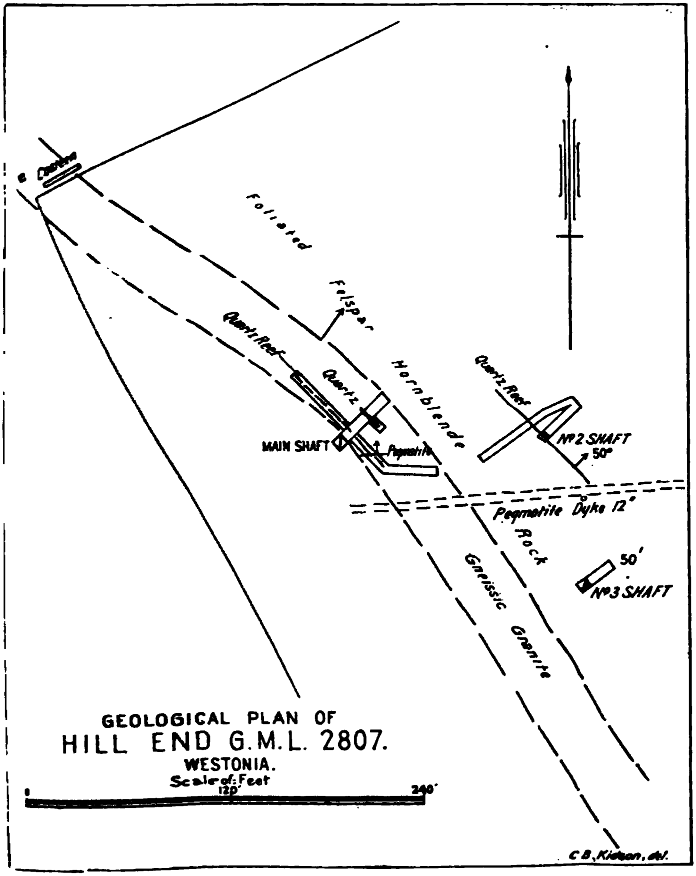
The mine is situated in greenstone country, and lies near or at the contact of this rock and the massive granite seen outcropping at Boodalin Soak. Owing to its proximity to the granite it may reasonably be expected that other granite dykes will be encountered in subsequent development.

Table showing the Yield of the Pertha M G.M.L. 2816.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	ozs.
1916	Pertha M., 2816	392·00	263·41
	Total	**392·00**	**263·41**

Hill End Mine, G.M.L. 2807.—The work on this lease (Fig. 21) has been chiefly confined to the exploiting from a shaft (main shaft) of a quartz vein running in and parallel to the sides of a narrow belt of gneissic granite.

Fig. 21.



Geological plan, Hill End Gold Mine.

This gneissic granite is similar to the Edna May belt. There is no reason to doubt its intrusive nature, also its age being greater than the pegmatite epoch.

The underlie of the shaft is 60 degrees, which represents the dip of the reef.

At a depth of 45 feet vertical the reef has been opened out with a drive going south-east for a distance of 27 feet. In this drive the reef averages probably 18 inches. In the north-western drive the reef is not so well defined. Immediately below this level the sulphides appear. The shaft has been sunk to a depth on the underlie of 72 feet.

About 12 feet below the 45ft. level a drive has been put in south in the sulphide zone. Here an excellent hanging wall is seen, and a regular reef heavily charged with pyrites. Visible gold is common in this stone, and the owners showed me some excellent pan prospects.

The country here is very hard. One or two very small pegmatite dykes are seen crossing the reef, but appear to have no effect on either its continuity or gold contents.

Hill End No. 2 *Shaft.*—This shaft has been sunk 60 feet on the underlie, following a more or less irregular body of quartz of an average width of some 36 inches. At the bottom of the shaft a crosscut was started on a bearing of 238 degrees, and extends for a distance of 70 feet. As may be seen on the plan* the end of this crosscut is trending towards the end of the crosscut in the main shaft. Except for a few small quartz veins, nothing of importance was intercepted in this crosscut. The prevailing rock was greenstone in a more or less altered form; mica is common, being derived from the decomposition of the hornblende. This is more conspicuous near the lode than elsewhere.

No. 3 *Shaft.*—This shaft has been sunk 50 feet on the underlie. A crosscut 17 feet in length has been put out to intercept the gneiss, but was not continued a sufficient distance to effect this object. The country intercepted was greenstone, in which the mica was replacing the hornblende. These workings are all in the oxidised zone.

Table showing the Yield of the Hill End G.M.L.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		tons.	ozs.
1915	Hill End, 2807	126·00	93·44
1916	Do.	68·00	43·43
	Total	**194·00**	**136·87**

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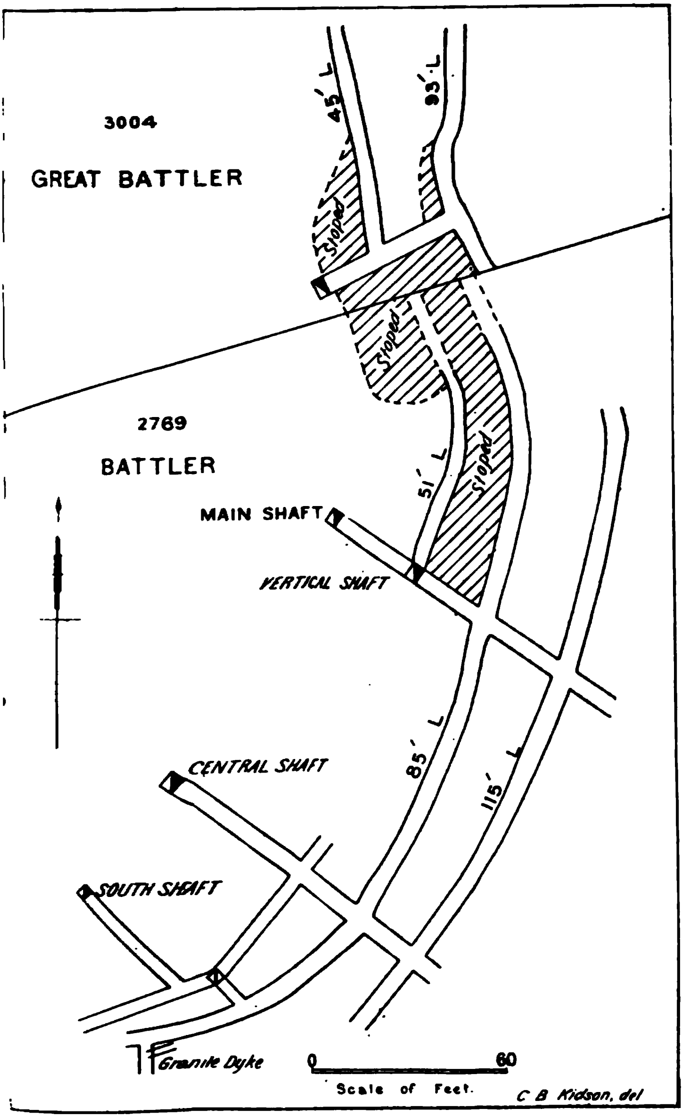
* Fig. 21.

Battler (G.M.L. 2769) and Great Battler (G.M.L. 3004) Mines.—These mines are situated near the townsite of Battlefield, st of Boodalin Soak.

Fig. 22.



Plan of workings, Battler and Great Battler Gold Mines.

Geology.—Three classes of rock are represented.

First, a narrow band of granitic gneiss in which the quartz vein or lode occurs. This band is surrounded by the prevailing greenstone. In both the above are typical pegmatite dykes.

The gneiss, which is but a narrow dyke mass, highly foliated, has been already fully described both in the text and appendices.

*Mine Workings, Battler.**—The principle mine workings are connected to a main underlie shaft.

No. 1 *Level.*—This level extends north from the shaft into the Great Battler and a short distance south of the shaft. The vertical depth is 51 feet, and on the underlie 59 feet.

A stope has been taken along the whole level, so width of stone not ascertainable. The south face was blocked and not accessible.

No. 2 *Level.*—Vertical depth 85 feet. From shaft to boundary the ore has been broken to the 51ft. level. Southward the level extends past the south shaft.

Between the main and central shafts the quartz vein is very small, except for a length of about 20 feet, when it is seen to have a thickness of from six to eight inches. The reef has practically vanished south of the central shaft.

In the extreme south of this level a pegmatite dyke is seen crossing the south face. The strike of this dyke, though uncertain is north of east, with a dip to the west.

No. 3 *Level.*—Vertical depth 115 feet. A drive at this level connects the central and main shafts. It also extends some 20 feet south of the central shaft and 60 feet north of the main underlie shaft.

Between the two shafts the thickness of the quartz vein is variable, but in no instance was it more than 12 inches thick and often only three to four inches.

A stope was started 60 feet south of the main shaft, where the stone was about 10 inches wide.

North of the main shaft, for the 60 feet driven, the average thickness of the vein was about six inches.

Throughout the mine the quartz vein is small and irregular. The encasing gneiss is not payably auriferous.†

As greater depths are being reached the encasing rock is getting perceptibly harder. The mine is a comparatively dry one, water being almost absent.

The Great Battler.—The quartz vein being worked in this mine is a continuation of the one in the Battler.

Two short levels have been opened from an underlie shaft situated close to the southern boundary.

From the first of these, the 45ft. level, a stope, some 60 feet in length, has been carried up to the surface.

North of this stope the vein had practically vanished.

In the shaft the vein appears to be not more than four to six inches wide.

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* Fig. 22. † Manager's word for this statement.

The second level has a vertical depth of 93 feet. Some 25 feet north of the shaft the reef makes a sudden bend, and in this bend a nice body of stone was found. Unfortunately, however, it soon cut out into a mere thread.

The walls of the lode in the Great Battler are similar to those in the Great Battler, viz., gneiss, and as this band is found on the surface some considerable distance north of the present workings there is still a chance of finding more stone by driving north in this ore channel, otherwise the mine must be considered as one containing a very small tonnage of fairly high-grade ore as the following official returns show.

Table showing the Yield of The Battler and Great Battler Reefs.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.
		Tons.	Ozs.
1915	Battler, 2769	115·00	170·64
1915	Edna May Battler G.M. Co., N.L., 2769	243·00	195·97
1916	Do.	1,745·00	1,713·39
1916	Great Battler, 3004	50·50	68·86
	Total	**2,153·50**	**2,148·86**

Violet May Mine G.M.L. 2878.—On the south-western boundary of this lease are two shafts sunk to develop some irregular artz veins in a very coarse pegmatite dyke.

The underlay, or northern shaft, has a vertical depth of six feet. and then on the underlie for a distance of 27 feet at an angle of 55° towards the north-east.

The dyke is in the footwall of the shaft. At the bottom, the hanging wall is exposed. A small hole in the footwall of the shaft exposes the footwall of the dyke, which has a thickness here of eight feet six inches. The quartz veins being worked are irregular, both in size, shape, and direction. In some places the dyke is highly felspathic, in others extremely acid. This latter phase is particularly noticeable in the southern shaft. This shaft has a vertical depth of 28 feet and has just struck the granite in the bottom.

It is asserted by the owners, Messrs. Hansen Bros., that gold is found in appreciable quantities in the dyke itself. It is probable that the same dyke extends into lease 2879. A lot of dry-blowing and costeening has been done near this boundary, which would indicate that some lode or other is shedding gold. There are indications of other dykes being present in this vicinity, but they have not been exposed sufficiently to map.

XIII.—CONCLUSIONS.

The Westonia belt consists of a series of rocks comprising sediments (metamorphic) and intrusives of both a basic and acid character. Surrounding this complex is the massive granite.

The sediments, from a mining point of view, are not an important type of rock, for they are neither metalliferous nor auriferous.

Of the intrusives the principal types, taken in order of age, are the following:—

A.—The prevailing foliated hornblende felspar series, the typical greenstones of the area.

B.—Acid gneisses. Of these the best example is the Edna May lens, with the subordinate equivalents at the Battler and Hill End mines. These are, from a mining standpoint, the important rocks in that they contain, with minor exceptions, the payable lodes of the district.

C.—Basic igneous rocks. These occur as intrusives into classes A and B in the form usually of narrow dykes. They are of an extremely basic character, and are technically termed hornblendites.

D.—A double series of acid dykes or apophyses.

- I. An ultra acid variety, highly auriferous and of a greater age than Class C. Of this variety the main lodes of the Edna May consist.
- II. A later, in fact the latest, series of intrusives occurring in the form of normal pegmatites and white aplites, both essentially non-auriferous.

Recent surface deposits, the partially stratified talus of the country rocks, payably auriferous in one instance, were traced in the vicinity of the outcrops of the main lodes of the Edna May group.

Reviewed from a mining standpoint, the facts obtained point strongly to the following conclusions:—

(1) That the gneissic areas, though very limited, have up to the present only been partially prospected, also, it is evident that the main gold-bearing lodes occur in those areas.

(2.) Outside the gneissic zones the quartz veins which have been found have proved very small and erratic, with two doubtful exceptions, the Recovery and Pertha M lodes.

The possibilities, therefore, are that new lodes will be found in the main gneissic area (in particular), and minor veins of a payable nature in the surrounding greenstones.

The longevity of the main lode is extremely probable, though of course, the gold contents at depth will be problematical.

There is no reason why fresh gneissic areas should not be located, but prospecting for such would be extremely difficult and their discovery merely fortuitous.

It might certainly benefit prospectors to look out for gneissic rock first, in their pursuit of gold-bearing lodes, searching carefully in any areas of this class of rock they may locate; it would certainly enhance their chances of success.

XIV.—COUNTRY SOUTH OF CHERITON'S.

GENERAL DESCRIPTION.

After travelling southwards from Cheriton's along the beaten track, for a distance of above four miles a noticeable change takes place in the vegetation, surface rocks, and surface configuration. In place of the morrell forests and gimlet wood thickets one sees only stunted vegetation, with an occasional clump of gums, and in the spring time an abundant variety of wild flowers noticeably different from those of the northern portions of the field. The rocks here exposed are either granite or remnants of an extensive sedimentary series.

The surface instead of being hilly and rough, is undulating, with occasional elevations which have the appearance of hills when viewed from a distance, but do not rise to any appreciable altitude.

There is little if any change from this class of country till Mount Holland is reached, when similar country to the Parker's Range district is encountered. A narrow strip of greenstone country, running more or less parallel to the road as far south as Hatter's Hill, is responsible for this change.

Hugging this greenstone belt on the west from Mount Holland to Mid-Ironcap is a belt of sediments resembling closely those to the west of Parker's Range and Cheriton's.

The North Ironcap is a conspicuous land mark in this series.

Passing through the Mid and South Ironcap, both of which are two conspicuous landmarks, is a similar belt of sedimentary rocks, with identical lithological characteristics.

From Hatter's Hill to Cowjenup plain country is the prevailing type, in which are occasional granite knobs, conspicuous amongst which is Mount Gibbs.

Just visible to the east or north-east from the highest points of the above-mentioned the tops of the hills of Bremer Range can be seen in the far distance, with occasional glimpses of the intervening lake country: the south-western extension of the Johnstone lake series.

From Iron Cap to Bremer Range the country presents little, if any, change.

At Cowjenup a tributary of the Oldfield River has cut a deep channel through the surface debris down to the granite, which alters the configuration of the surface slightly, but is not worthy of further notice.

The track of the Rabbit-Proof Fence traverses pronounced undulating country; most of the road is sandy, with occasional ironstone gravel—(laterite)—patches, on the crests of the higher ground. Conspicuous outcrops of granite are common and form the only relief to a most monotonous landscape. Similar country extends westward of the fence as far as the eye can reach.

WATER SUPPLY.

During the winter months of average rainfall there is an abundant supply of water on the granite rocks, but this cannot be counted on during the summer months.

On the main road to Cowjenup from Cheriton's the following waters are more or less permanent:—

Split Rocks—8 miles south of Cheriton's.
Mount Holland—17 miles south of Split Rocks.
Government Tank—18 miles south of Mt. Holland.
Digger Rocks—20 miles south of Government Tank.
Hatter's Hill—12 miles south of Digger Rocks.
Mt. Gibbs—7 miles south of Hatter's Hill.
144-Mile Rabbit-Proof Fence—8 miles south of Mt. Gibbs.
154-Mile Rabbit-Proof Fence—10 miles south of 144-Mile Rabbit-Proof Fence.
170-Mile Rabbit-Proof Fence—16 miles south of 154-Mile Rabbit-Proof Fence.

On the Rabbit-Proof Fence from Burracoppin to Cowjenup, there is a good supply of water at short intervals, but this can only be used by special permission from the Government Inspector.

The track from Forrestania to Bremer Range is not so well watered, but during the wet season the supply is adequate for prospectors.

After leaving Forrestania the first water is reached on a travelling distance of 10 miles; this is known as Allen's soak. There is plenty of water here but it is more suitable for stock than drinking purposes, the water being very dark, due to decaying vegetation.

After rain, water can be obtained in abundance at distances of 17 and 26 miles east from Allen's soak. At a distance of nine miles from the last, that is 36 miles from Allen's soak, there is another soak which yields a good supply of water but is decidedly brackish owing to its proximity to a salt lake.

However, six miles east from this is what is likely to be a very permanent supply of good drinking water. This is also a soak from granite rocks. Considerable quantities of water were drawn here without exhausting the supply. In the summer months this is the only known permanent water supply for Bremer Range, and, by the road, is 17 miles west from Mount Gordon.

A new tank has been excavated near the leases at Forrestania which with a natural clay-pan catchment should yield a more or permanent supply when once filled, unless very extensively drawn upon.

There is usually water at Native Rock, immediately to the south of North Ironcap.

With these exceptions, the water supplies can only be relied upon during the winter months, or a short time after rain for, as a general rule, the clay-pans and rock-holes are too shallow even when completely filled to last any appreciable time during the summer months.

One main cut track extends from Southern Cross southwards to the Rabbit-Proof Fence, intersecting the fence at the 144-Mile post.

For the most part, from Cheriton's the track is sandy and only partially cleared of stumps and roots, but has, nevertheless, been traversed successfully by teams and several motor cars.

The track on the Fence itself, though sandy in places, has been well cleared for vehicular traffic, but can only be used, as already stated, by special permission.

The other routes marked on the maps are merely bush tracks and usually very rough and heavy, notably the one from Forrestania to Bremer Range.

TIMBER.

Taking the area as a whole, timber is scarce, though there are occasional small belts of gum and gimlet wood suitable for mining purposes. The best supply is, without doubt, on the greenstone belt lying between Mt. Holland and Mid Ironcap.

GEOLOGICAL FEATURES.

The rock types of the area under review may readily be classed into four groups:—

(1.) Granites and their apophyses.
(2.) Greenstones—(a) Older series.
    (b.) Later series, dolerites.
(3.) Sedimentary rocks.
(4.) Superficial deposits.

Taking the area as a whole, considerable difficulties present themselves in the mapping of these rock types, as is generally the case on the Eastern fields, but more particularly so in this area, as the greater portion of the surface is not only masked by superficial deposits but often by dense scrub.

In the granite areas the overlying debris is chiefly sand or loam with not infrequent patches of siliceous and less common ferruginous laterites.

These deposits are derived from the disintegration of the granite itself, the breaking up of the remnants of a once extensive sedimentary deposit and, in a lesser degree, to the waste from the massive greenstones and recent dolerite dykes. In consequence, many square miles of the surface present nothing else to the observer than sand-plains, with very occasional outcrops of granite, and more rarely, isolated patches of highly altered sedimentaries.

In addition, except where bush fires have lent a helping hand, much of the surface—and this applies to the greenstone areas as well—is overgrown with thick scrub matted with fallen timber and vines. These surface conditions, together with the scarcity of water, the abundance of poison plants, etc., make the accurate mapping of this area extremely difficult, and only possible by prolonged work and an expensive and complete outfit.

The boundaries, as delineated on Plate V., must, therefore, only be taken in a broad sense and as a reconnaissance survey only.

SUPERFICIAL DEPOSITS.

Scattered almost universally over the underlying rocks is a mantle of debris varying in thickness from a few inches to several feet; the composition of which varies almost as much, if not more, than the thickness.

Typical sections, however, often show the upper layers to be loose, incoherent sand and ironstone nodules overlying a mixture of sand and loam, in which are numerous rock fragments. Still deeper the mixture is often cemented with a hard compact conglomerate rock, the cementing material being either lime and iron oxides or silica, or a combination of all. In other instances, clay beds have been cut under the overlying sand, which, being impervious to water, are found extremely useful in the formation of water reservoirs. A less frequent covering are the ferruginous and siliceous laterites, the latter, as a general rule, being indicative of underlying granite.

There is little doubt that the lake beds are built up to a considerable depth with recent deposits, but there was no opportunity of studying their composition. The upper layers are composed of very fine sediment impregnated with magnesium and sodium chlorides, and in which gypsum is commonly found.

Scattered through the sand-plains are numerous small belts of red soil. It seems more than probable that these patches are derived from the washing away of basic dykes, the dykes being probably dolerites of a later age than the granites. This is certainly the case in some instances.

SEDIMENTARY ROCKS.

With two exceptions the rocks of this class are only represented by scattered remnants.

After leaving Cheriton's, as already related, the greenstone belt ceases and the country opens out into more or less undulating plains, with occasional rises and granite knobs to break the monotony.

On the higher ground it is not at all uncommon to find remnants of rocks resembling in many lithological details the beds of sedimentary origin found in the Parker's Range and Marvel Loch, which have been fully described in a previous report.*

It has been found impossible to map these isolated patches in detail, but general boundaries have been fixed to embrace that portion of the surface where such outcrops predominate.†

South of Mount Holland, however, a belt of this class of rock is fairly well defined and continuous, and extends to the west of Mid Ironcap.

Another well-defined belt, and probably a continuation of the first, extends further south with the same strike, but with a reversed dip through both the Mid and South Ironcaps.

On the three "Ironcaps" which form the highest points of the district, portions of these beds are well exposed. In each instance they are found to consist of well-banded quartzites; in most instances highly ferruginous.

The iron occurs in the form of limonite and haematite. In places the beds are decidedly magnetic.

Folding in the strata is of common occurrence. The strike varies from north to north by west or east with a dip at a high angle to the west in the southern belt, but slightly to the east at north Ironcap, and also near Mt. Holland.

It seems probable that these beds form the southern continuation of the series found in the mid and northern portions of the Yilgarn Goldfield, and may be related to the Stirling Range beds.

As regards their age, there is no doubt in the writer's mind that they are older than the greenstones and have been intruded by the latter. Hence they are probably the oldest rocks of the district. From an absence of fossil remains their geological age is not determinable, but they are probably Pre-Cambrian.

From an economic point of view they are, so far, of no value, as they do not carry minerals of commercial value and have not proved to include auriferous quartz veins, or carry self-contained gold in payable quantities.

GREENSTONES.

These are readily divisible into two classes:—

A. A massive variety of the Marvel Loch type.
B. Dolerites.

A. *Massive Greenstones.*—Where exposed, in the areas under immediate review, the rocks of the massive variety are found in the foliated, massive fine-grained and massive coarse-grained forms, the first usually occurring as a selvedge to the two latter.

There is such a close similiarity of these types to those of the Bullfinch-Southern Cross-Marvel Loch that a detailed description is unnecessary here, as the reader can refer to the previous pages of the present bulletin, and also Bulletin 63 for further details.

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* **Bulletin 63, page 29, *et seq.***
† **Plate V.**

B. *Dolerites.*—Numerous intrusive dykes of an apparently fresh rock are met with in the working of the Forrestania field. Further reference will be made to these dykes in the descriptions of the mine workings. Petrological examinations of samples broken from the rock in the underground workings are to be found in the Appendices.

GRANITES.

In mapping the granite, as a general rule, any area covered with sand or siliceous laterite was included under this class of rock. The granite rock itself comparatively seldom comes to the surface, and, when it does, usually occurs in irregular masses outcropping on the crests of the higher ground, forming in many instances a conspicuous landmark. Specimens taken from some of these masses have been described by the Petrologist, and in each case have proved to be microcline biotite granite, closely resembling the granite of the Southern Cross type. (See appendices.)

In the Forrestania area the main rock mass is a granite highly decomposed near the surface. The rock, even in this weathered condition, has a distinctly gneissic appearance, the planes of foliation apparently running east and west with a general dip to the north.

Descriptions of the Mining Centres in the Southern Area.

XV.—FORRESTANIA.

The following report was made on 27th July, 1915:—

Location.—The new field is situated in the extreme south of the Yilgarn Goldfield at a distance of eight miles north 60 degrees east from the Mid Ironcap, and 13 miles due east of the 95-mile post on the Rabbit Proof Fence.

ROADS.

There are two main tracks leading to the field from the Eastern Railway. Of these, the better is the one passing through Parker's Range, Cheriton's, and Mount Holland. This track is in fair order as far as Cheriton's, and though cleared of timber is very rough for general traffic for the remainder of the distance. The other route turns off the Rabbit Proof Fence from either the 79 or 88 mile post. The one followed was the former, and it is extremely heavy as far as Wattle rock, where the other from the 88 mile joins. From here the route passes by the north Ironcap and connects with the Ravensthorpe track about five miles to the north of the Government Tank. The road down the fence is very heavy, the sand having filled in the wheel ruts during the recent wet season.

From Southern Cross by the first route the total distance is miles, and by the Rabbit Proof Fence 124 miles to the Central s. A somewhat shorter route from the railway line would be m Yelladine, a railway siding 20 miles east of Southern Cross.

GEOLOGY OF THE FIELD.

The leases are situated in granitic country, apparently a por- n of the main granite belt. Unfortunately, the underlying rocks e almost completely covered with an overburden of sand and ginous gravel, but there are sufficient outcrops of the decom- d rock to verify the above statement. Lying to the north-west the lease is rather an extensive belt of greenstone of the Marvel n type and, probably, a continuation of the same belt. Another ll belt of similar rock outcrops about four miles south of the ard lease.

LEASES.

Unfortunately, very little development work has been done on y of the leases and, to date, only one reef can be positively said o exist.

The indications from quartz floaters, however, would point to e possibility of other veins being exposed at an early date. There s a marked parallelism of the fine lines of floaters, the general ike being north 70 degrees west.

On account of the parallelism it seems more than likely that e granite will be found to be gneissic in character, the quartz ns following the planes of foliation.

On the Reward lease two costeans, about 200 feet apart, reveal a reef at least seven feet wide in one place, and three feet in the ern end.

The floaters extend over a distance of some 700 feet. Care- lly broken samples of the reef exposed in these costeans gave a ult in each case of slightly under 3 dwts. of fine gold per ton.

Samples from the floaters on the Premier, Commonwealth, osi, and Allen's Find were crushed and panned off in the field, d the stone was found to be gold-bearing, but, in the writer's nion, the values obtained were low, and scarcely payable. It ems probable that higher values than justifiable have been given y prospectors on account of the low value of the gold not being ken into account. This should be guarded against in the future. Taken as a whole, the reports of the field have been very much aggerated, and against such the people should be warned. On other hand, gold has been found over an extensive area in new ntry and, as practically no development has been done, the ex- nditure of a limited amount of capital is justifiable.

WATER SUPPLY.

Both tracks are supplied with water at intervals sufficiently short to accommodate the travelling public. Appended is a list of the supplies and distances. The main supply for the field itself would be obtained from a Government tank, 20,000 gallons capacity, on the Ravensthorpe road, and situated about six or seven miles, as the crow flies, from the leases. At present there is no direct route, and the distance by a bush track is at least 10 miles. Owing to the late rains surface soak water is being obtained in shallow holes in the sand close to the leases. This supply should be exploited further, as little expense would be entailed, and, if successful, would be extremely useful to augment the permanent supply. With economy, there would be sufficient water to prove whether the field warrants further permanent water conservation. A justifiable expense would be incurred in cutting a direct track from the Government tank to the leases, and it would undoubtedly be much appreciated if the track from Cheriton's to the field was cleared of mallee roots and stumps.

The following is a list of water tanks, etc., with distances from Southern Cross to the new find:—

——	Distance in miles.	Nature of Supply.
Southern Cross to Marvel Loch	22	Scheme water.
Marvel Loch to Parker's Range	14	Parker's Range Government tank. Dingo tank, 50,000 gals., full.
Parker's Range to Dulcie Jean	10	Dulcie Jean tank, 50,000 gals., full.
Dulcie Jean to Split Rock ..	16	Split Rock well, 8,000 gals., not permanent in summer.
Split Rock to Mount Holland ..	16½	Mount Holland tank, 12,000 gals.; 6,000 gals. at present.
Mount Holland to Government tank, five miles north of turn off W. the field	20	Government tank, 100,000 gals., full.

On the Rabbit Proof Fence there is sufficient water (surface) at the rocks marked on accompanying plan for travellers, but such is not permanent during the summer months.

MINES.

Since the above report was written a limited amount of mining development has been done to a vertical depth below the surface not exceeding 60 feet. A detailed account of the individual mines will be found in the following pages of this report under the heading of Mines.

Geologically there are a few points of interest brought to ht which were not too apparent at the surface. In the first lace the country rock has proved to be a highly kaolinised rock, ugh which are distributed quartz veins of uniform size having e appearance of primary quartz. Fine grains of mica are also mmon throughout, though apparently this is only the residual f a much greater amount. There seems no doubt as to the rock ing a highly kaolinised biotite granite. Lines of foliation in the k mass, which are not always too apparent, tend to point to a re or less original gneissic structure. In several of the mines rrow basic dykes were encountered. So far these have been oved to have no great thickness and, as a general rule, conform h the prevailing strike of the reefs and lines of foliation in the nite, *i.e.*, a general east and west trend with a prevailing dip to e north. The occurrence of these dykes and their relationship he granite and quartz reefs is clearly set out in Figs. 23, 24, 5, and 26.

The following are two petrological descriptions of samples col- cted from the basic dykes found in the Reward and Common- alth leases:—

Reward Lease, G.M.L. 2909.

The rock is a fine-grained amphibolite derived from a dolerite or e-grained gabbro, and is similar to specimens from the Canning River res, and consequently to some of the Darling Range greenstones. It s not, however, the same rock as the Corinthian dyke, which is a fresh ite dolerite, and probably later in age.*

Commonwealth Mine, G.M.L. 2916.

The rock is a fine-grained, partially chloritised amphibolite with e hornblende in great excess over the colourless constituents. These sist of felspar and a little quartz. Shearing was not noticed in the tions nor any gneissic structure. It is doubtless derived from a fine- rained dolerite similar to sample from the Reward lease.*

With regard to the quartz reefs, as can be observed from the ription of the individual mines, they have so far proved, under ting conditions, to be unpayable as gold producers; also, as a neral rule where opened out, they have proved to be smaller and lower grade at depth than at or near the surface.

Furthermore, that where payable values have been formed at a th the gold occurred near faults which points to the higher values ing probably due to secondary enrichment.

Development work has also shown in several instances that the artz bodies are apparently much larger at the surface than in the d country below. This is particularly noticeable in Smith's, M.L. 2970, and the Great Southern No. 1, G.M.L. 2911.

Careful observation shows this is apparently due to the dis- egration of the original reef outcrop and the accumulation and rying of the debris. "Surface creep" probably played an active rt also in this concentration of the quartz in the surface rock.

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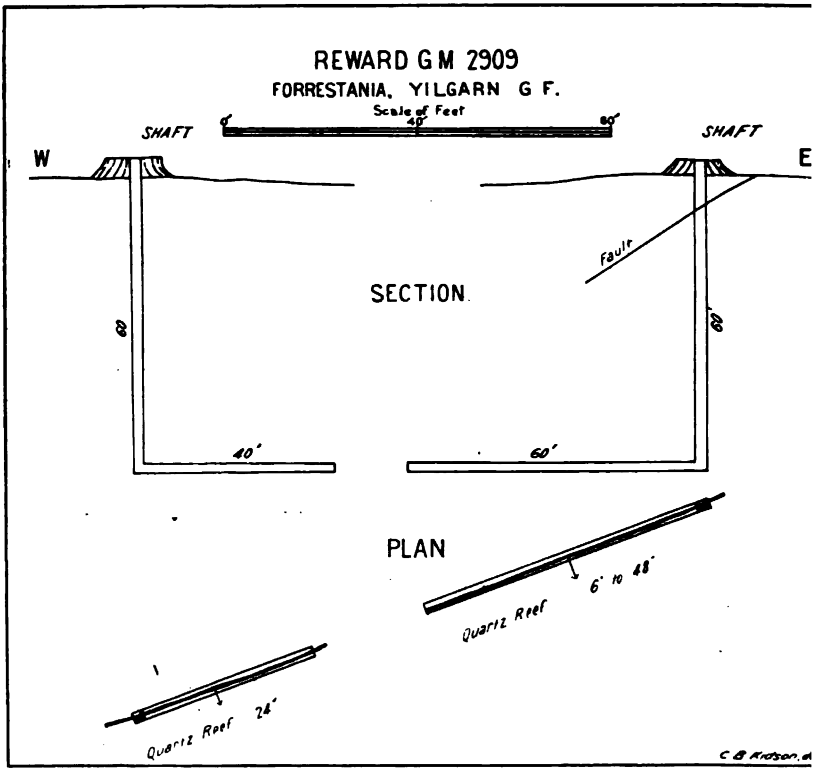
* R. A. Farquharson, Petrologist.

Reward Mine, G.M.L. 2909.

Two shafts (Fig. 23) situated approximately in the centre of the lease and 400 feet apart, have been sunk to vertical depths of 60 feet.

The western shaft was sunk on the reef which has an average thickness of about two feet. A drive east for 40 feet on the reef proved the reef to be continuous for this distance with approximately the same thickness, but reported low-grade values.

Fig. 23.



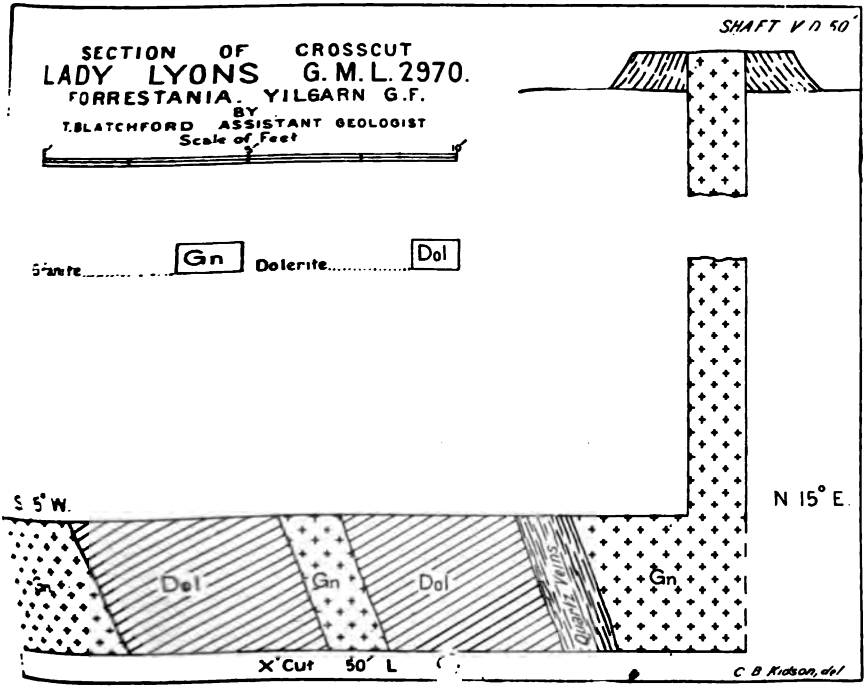
Geological plan of workings, Reward Mine, Forrestania.

The western shaft intersected the reef at a depth of 33 feet and passed through same at the bottom of the shaft. A drive has been made on the footwall of the reef 40 feet west. From this drive, boreholes pierced the reef at regular intervals, and the manager informed me that the average thickness of the reef varied from six inches to four feet, with low gold values. At the bottom of the shaft the reef is probably six feet thick at least. Twenty feet down the shaft the reef has been intersected on the south side of the shaft. At this point the reef is faulted; the fault plane dips to the south-west. Above this fault gold values are higher. Insufficient work had been done to take exact measurement of the precise amount of faulting, but it is evident the reef has been moved only an inconsiderable distance.

On the surface immediately east of the east shaft the outcrop has been costeaned and some of the stone contains coarse, visible gold, the extent of which is uncertain; probably it will be found to have some connection with the fault which could easily come up about this point, and, if so, the increased gold value may be secondary enrichment only. The outcrop north and south of this point certainly does not contain high or even payable values.

The strike of the reef on the surface is north 70deg. west with an underlie at a steep angle to the north.

Fig. 24.



Geological plan of Lady Lyons Gold Mine, Forrestania.

Lady Lyons Mine, G.M.L. 2970.

This mine was formerly known as Smith's show.

On the surface there is no doubt that floaters could be picked up which would yield appreciable amounts of gold when concentrated by crushing and by panning off with water.

However, a shaft was sunk (Fig. 24) and a crosscut driven south for a distance of 30 feet. with the result as shown on section.

The occurrence of the dolerite dykes in this crosscut are interesting, and clearly show that their strike corresponds to the prevailing strike of the quartz reefs, or, in other words, that there is a prevailing parallelism of the two. Comparing the two rocks, the dolerite and granite, there is a marked difference in their relative decomposition. For the most part the dolerite may be considered only partially weathered, the weathering becoming perceptibly less as greater depths are attained. On the other hand, the granite is highly decomposed and still friable to the touch of even the hand, and shows no sign of becoming harder and massive. There is no doubt in the writer's mind that the dolerites are intrusive and of a much later age than the granite, also that the quartz reefs are associated with the occurrence of the greenstone intrusives and are of later age than the prevailing quartz reefs of other portions of the Yilgarn Goldfield. Furthermore, in this and other mines the quartz veins are seen to occur in the granite and near the junction of the dyke and running parallel with the latter rock.

In no instance was there any indication of the dolerite dykes attaining any great thickness, the two in this mine being approximately nine feet each.

GREAT SOUTHERN No. 1 MINE, G.M.L. 2911.

One shaft (Fig. 25) has been sunk on this lease to a vertical depth of 50 feet, from the bottom of which a crosscut has been driven in for a distance of eight feet south. In the end of the crosscut the reef was intersected, also a dolerite dyke. The reef is at the junction of the dyke and the country rock pierced by the shaft. which is highly decomposed granite. Drives were made four feet east and six feet west on the course of this reef. The thickness of the reef intersected is but a few inches and is unpayable. On the surface the reef had every appearance of considerable size and gave promising gold prospects.

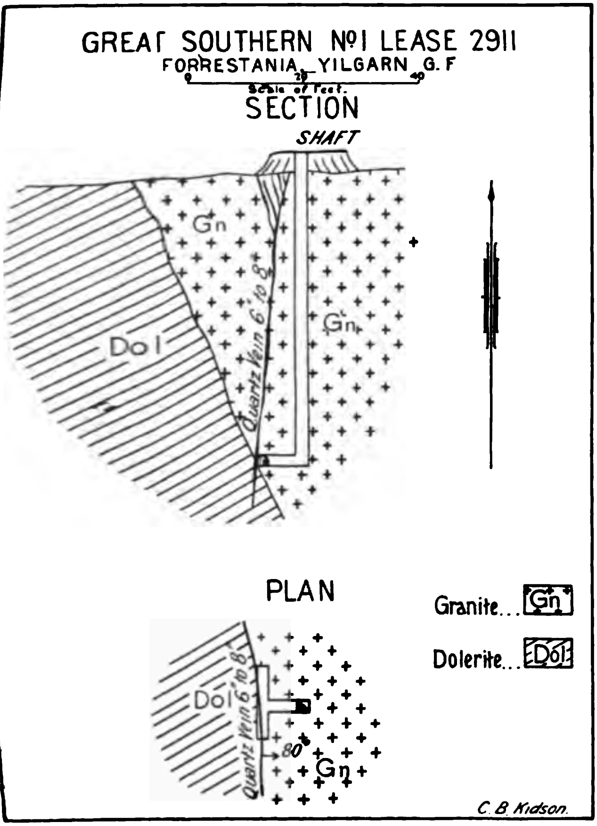
COMMONWEALTH MINE, G.M.L. 2916.

As may be observed on the accompanying plan and section (Fig. 26), development work on this lease has been carried on from two shafts at vertical depths of 60 feet.

Taking the western shaft first, crosscuts were made from the bottom of the shaft 15 feet north and south. In the northern crosscut a greenstone dyke was pierced but no lode found. In the southern crosscut a small vein of quartz was found at the end of the crosscut, and on the junction between the greenstone dyke and granite. The reef was too small and too low in gold contents to be of any commercial value.

In the eastern shaft the country pierced was granite, and a crosscut south 40 feet in length revealed the same rock for the whole distance. If the line of "floaters" on the surface were indications of a permanent reef it should have been, under normal conditions, intersected in these workings.

Fig. 25.

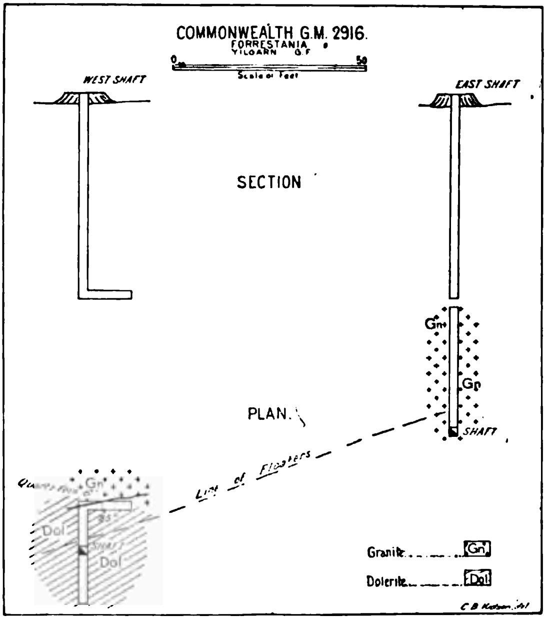


Geological plan of Great Southern Gold Mine, Forrestania.

PREMIER MINE, G.M.L. 2913.

Only a limited amount of prospecting has been done on this lease. Except for a few very shallow costeans, the development consists of one shaft at present eleven feet deep, where it is boarded over. The total depth is a few feet greater than this. This shaft has been sunk on the reef, which is much broken up near the surface. At the depth of eleven feet it was covered over and a small drive made on the west side. There is apparently a fissure in the reef at this point, which pitches to the west at a fairly low angle. Out of this small drive, which runs north 60deg. west, a crushing of five tons was taken which gave a reported result of 13dwts. of gold per ton, the exact value of which was not stated. In the face of the drive above-mentioned the quartz had a thickness of at least three feet.

Fig. 26.



Geological plan of Commonwealth Gold Mine, Forrestania.

The country rock on the south side is granite, but that on the north side is doubtful, the rock here being too decomposed for a definite determination.

Black Prince Mine, G.M.L. 2961.

Only one shaft has been sunk, on a reef some two feet wide, to a vertical depth of 11 feet. At the bottom of this shaft the reef was 20 inches thick. A sample of the reef broken from the sides of the shaft returned 10dwts. to the ton by fire assay, over a width of 20 inches. The strike of the reef is north 70deg. west with an underlie of 85deg. north.

Since the date of my inspection the owner told me that they had continued the shaft and the reef had become smaller and the values lower.

Near the surface the owners proved that payable gold occurs in the seamy portions of the reef. These seams consist of almost pure clay with a little iron intermixed. The gold in the seams is inclined to be of a coarse nature and readily separates from the gangue. Hence, in taking samples from the bottom of the shaft there is a likelihood of the sample being enriched from the gold loosened from the clay by repeated firing.

PART B.

MOUNT JACKSON AND MARDA CENTRES.

BY

C. S. HONMAN, B.M.E.

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I.—INTRODUCTION.

The field work in this region was commenced towards the end of July, 1914, and continued until the end of January, 1915. The area mapped and described below covers about 4,500 square miles; includes the country between the Mt. Jackson-Southern Cross road and the Rabbit-Proof Fence from the 35-mile to the 126-mile post on the latter; and between Mt. Jackson and the eastern boundary of the Yilgarn Goldfield, including Pigeon Rock, the Die Harty and Bungalbin Ranges.

The mining centres of Jackson, Marda, Koolyanobbing, and Yarbu have been examined in greater detail than the intervening tracts of country.

I am indebted to Mr. Simpson for the determination of a number of minerals and Mr. Farquharson for the petrological examination of rock specimens, also to the mine managers and prospectors of the district for facilitating in every possible way the examination of their mines and claims.

Mr. Woodward has previously reported on this area on a reconnaissance trip through the North Yilgarn and southern portion of the North Coolgardie Goldfield, which he describes in Bulletin 46. The broad outlines of Mr. Woodward's mapping of the district was of great assistance as a basis for the more detailed work described in this report.

Except for the mining districts of Jackson and Marda the mapping has been done on a scale of 300 chains to the inch and reproduced on a scale of four miles to the inch. (Plate 1.)

Greater detail is shown on the maps of the Jackson and Marda mining centres for which a scale of 20 chains to the inch has been used in the field. They are reproduced herewith (Plates 17 and 18) on that scale.

A number of plans and cross-sections of the various mines accompany this report.

The usual difficulties which attend field mapping in the Eastern Goldfields, viz., relative scarcity of outcrops and the large extent of overburden represented by sand plains and salt lake country, were encountered in this district.

The geology of the district is of more than ordinary scientific interest on account of the occurrence of a group of sedimentary rocks of younger age than the greenstone series, and resting unconformably on the latter. Owing to the strong lithological resemblance of these younger rocks to the Kurrawang Series in the Kalgoorlie district, it follows that an unconformity exists also in the latter district where, owing to the parallelism of the strike of all the rocks, no unconformity is actually visible.

II.—PHYSICAL FEATURES.

TOPOGRAPHY.

The topography of the region is typical of the Eastern Goldfields of Western Australia, and is that of a tract of country whose surface has been sculptured by a process of desert erosion. (See Plate 17.)

This area belongs to the topographical division described by Mr. Jutson in his work on the Physiography of Western Australia, Bulletin 61, as the Central or Salt Lake Division which, according to that author, is an elevated plateau of arid erosion.

The land forms in this region, as is generally the case in the Eastern Goldfields area, are not very diverse.

By far the most prominent land marks are the greenstone ranges at Mt. Jackson, around Pigeon Rock, Bungalbin, and at Koolyanobbing. These constitute the "higher land." Below this there is a vast tract of country which may generally be described as "sandy plain," and in the depressions of which occur strings of large salt lakes.

The "sandy plains" occupy by far the greatest area of the whole country.

Mr. Jutson has subdivided the Central or Salt Lake Division into a "new" and "old" plateau, which are chiefly divided from one another by breakaways of which the long line running east and west about 15 miles south of the Mt. Jackson ranges is an instance.

In the Mt. Jackson district the higher land attains an elevation of many hundreds of feet above the old plateau and probably represents the remnants of a still older land surface.

Whilst the higher land appears to be representative of an earlier cycle of erosion on the "old plateau," the salt lakes represent on the other hand, a later cycle of erosion on the new plateau, or a wide valley of mature erosion on the new plateau. (Fig. 27.)

There are several levels of breakaways though not as well defined as the main line that separates the old and new plateaux. For instance, there are cases of breakaways on the higher portions of the granite country. These are very disconnected and local and often below the level of large granite bosses. These higher level breakaways are probably the remnants af an older system of breakaways. This is very clearly shown by the mapping between Kalgoorlie and Coolgardie* where the new line of breakaways borders the lake, and remnants of the old line occur some miles behind the former.

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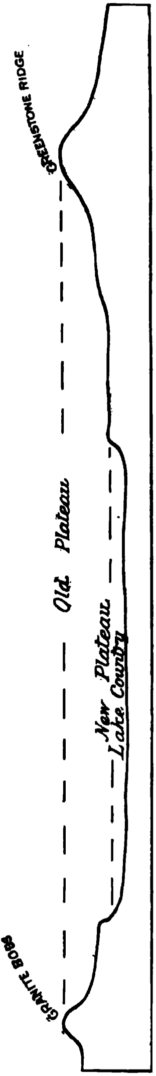
* Bull. No. 56.—The Geology of country between Coolgardie and Kalgoorlie, by C. S. Honman.

Fig. 27.



Diagrammatic section showing relation of old and new plateau.

The highest country is that around Pigeon Rock from which there is a decided fall to the south-west to the lakes at Yacke Yackine. This high country falls again to the north towards Lake

Barlee and apparently forms a dividing range between the Barlee and Southern Cross Lake system.

The ranges have a sinuous course corresponding with the trend of the ferruginous quartzites (Jaspers) in the greenstone series, and in fact owe their existence to the resistance to weathering offered by the quartzites.

When one considers that all the prominent peaks and ranges are composed of combs of ferruginous quartzites (Jaspers), it becomes evident what a very marked effect these banded quartzites have had on the natural relief of the region.

The ranges consist of razor-backed ridges which practically envelope the inlier of granite at Pigeon Rocks and are there known as the Die Harty Ranges. The northern portion of these ranges strikes north, and to the south divides into two arms, one trending to the south-east and culminating in a prominent peak called Mt. King; the other arm to the west crosses the greenstone belt south of Pigeon Rock and turns again to the south and follows the western boundary of the greenstone through Jackson.

At Jackson a number of parallel bands of ferruginous quartzite occur forming parallel ridges which turn again to the east-south-east, and passing south of Marda as one ridge, where its highest point is Mount Jackson Trigonometrical Station (2,200 feet by aneroid).

From Mt. Jackson Trigonometrical Station the range continues for over 20 miles to Bungalbin Trigonometrical Station, where it forms a group of steep ridges turning abruptly to the north-east.

The slopes of these ranges are steep, and rise from a gently undulating plateau of greenstone, which at no considerable distance from the ridges passes into sand plain which stretches as far as the eye can see, and whose monotony is only emphasised by the strings of salt lakes in the lower parts of the sand plains. When approached from the south the Bungalbin Ranges have a very imposing and rugged appearance.

The ranges around Pigeon Rock and the Mt. Jackson-Bungalbin range constitute in every sense of the term a "Divide" separating the Barlee lakes from the lakes of the Yilgarn. It may be termed the "Jackson Dividing Plateau."

Another range of mountains also corresponding with the ferruginous quartzites (jaspers) in a greenstone belt occurs striking north-west through Koolyanobbing Trigonometrical Station, which is, if not the highest, the most rugged peak in the range. The Koolyanobbing Ranges, as has been pointed out by Mr. Woodward,* occur in an area of depression, and are partially surrounded by salt lakes.

A characteristic and frequently occurring feature of the granite table-lands which occupy the north-west portion of the Yilgarn are the large bosses of bare granite, which have a very imposing appearance, and in some cases represent monadnocks of an earlier cycle of errosion on the old plateau. Examples of such bosses are Pigeon Rock, Elachbutting, Kurrakoppin, Walyahmoning, Barcooting, and many others, especially along the Rabbit Proof Fence.

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* Bulletin 46, G.S.W.A., p. 20.

The salt lakes form a connected drainage system with an irregular trend, and agree in this connection with Professor Gregory's idea of their being a dead river system. The direction of fall of the lakes is not certain without levels being taken; the main course being probably Lake Seabrook, which meanders about the Koolyanobbing ranges and connects with Lake Deborah, which has forced its way through the greenstone ranges just above Mt. Woodward, and is connected with Lake Brown.

Yacke Yackine Lake has a southerly trend, and has its source near Windarling Peak, at the foot of the Die Harty Ranges. It breaks through the Mt. Jackson ridges near Athlone and turns to the south past Yacke Yackine, where it spreads itself to the east and, finally taking a southerly course, joins the main line of lakes at Lake Deborah.

A line of lake connects the Koolyanobbing lakes (Lake Seabrook) to Lake Koorkordine at Southern Cross, and the latter falls slightly to the north-east, as proved by a topographical survey of Southern Cross.

The lowest level of the lakes is a little over 1,000 feet, and the highest peaks around Pigeon Rock, according to aneroid measurements, are not higher than 2,500 feet above sea-level. The majority of the country is a great undulating plain, varying in elevation between 1,000 feet and 1,500 feet above sea-level.

VEGETATION.

The vegetation of this country may be divided into two classes, according as it occurs on the north or south side of the Jackson Dividing Plateau. Thus we have two different types of vegetation.

(1) The Yilgarn or Coolgardie Type. South of Jackson.
(2) The Barlee Type. North of Jackson.

The Yilgarn or Coolgardie Type.—South of the Jackson Dividing Plateau the vegetation may be roughly subdivided into three groups, according as it grows on:—

(1) Greenstone country.
(2) Granite country.
(3) Lake country.

On the greenstone country we find different varieties of gum trees, viz., morrell gum, salmon gum, gimlet-wood, with an undergrowth of salt bush and stunted shrubs.

On the granite country there occurs mostly dense thickets of the jam-wood type, with patches of white gums and mallee on the higher portions.

On the lake country there is a comparative absence of the extensive salt-bush flats that characterise the Barlee country, and they become more scarce the farther south you go.

The timber country is much closer to the lake shore. Samphire is commonly found along the lake margins.

South of the divide large forests of good timber occur, whereas north the only timber is mulga and mallee.

The Barlee Type.—North of the Jackson Dividing Plateau the vegetation may also be roughly subdivided into the same three groups, but each having different characteristics to the corresponding groups north of the Plateau.

On the greenstone country we find mulga and an absence of gum trees of any description.

On the granite country, spinifex and mallee scrub. A species of desert pine is found growing on both greenstone and granite country, but is most abundant on the sandhills at the edges of the lake country.

On the lake country there is generally a fringe of samphire bush in immediate proximity to the dry salt lakes. This is followed by wide flats of salt bush, with occasional patches of quandong or native peach and sandalwood extending sometimes for a couple of miles inland from the lake shore. Outside the salt bush you find sandhills covered with desert pines and then, as the lake country is left behind, spinifex and mallee or mulga, according as the underlying rock is granite or greenstone.

Sandalwood is fairly evenly distributed on both types of country, though it is more noticeable around the dry lakes north of the divide.

WATER SUPPLY AND TRACKS.

The average annual rainfall of this region is below ten inches, and the scarcity of water is one of the great drawbacks that the prospector and pastoralist have to contend with.

There is no permanent natural water supply in the district. The pioneer had to depend on the catchments in rock holes of small capacity and hastily dug soaks.

These difficulties have been overcome as far as Jackson and Marda are concerned by the splendid work of the Water Supply Department by the building of large tanks in suitable catchment areas.

These artificial supplies are large earthen tanks dug in suitable position to catch the drainage from a group of hills, or are blown out of solid rock at the foot of large bosses of granite which serve as splendid natural catchments, supplying very clear water.

At Marda there is a tank roofed with galvanised iron and having a capacity of 500,000 gallons of water. The tank is excavated in decomposed greenstone and lined with asphalt. The catchment area is protected by three miles of fencing.

Along the Bullfinch-Jackson Road there are tanks at Golden Valley (30 miles from Southern Cross), 40,000 gallons; the 40-mile post small tank, blown out of granite; Ennuin, 200,000 gallons; Trough Well (48M.), small tank in granite; Currajong (61½M.), 200,000 gallons; Yacke Yackine (75½M.), 123,000 gallons; and at Jackson (85M.), 250,000 gallons. All these tanks are lined, roofed, provided with pump and trough, and the catchments protected by fencing.

Fig. 28.

Neg. 1351.

Photo: C. S. Honman.

The new track to Jackson is shorter than the surveyed road, but this is discounted by the much heavier and more sandy nature of the track and the scarcity of water, the only dependable supply being at the Native Well about 28 miles south of Jackson, which is a roofed, excavated tank in granite of 3,500 gallons capacity. Glasse's Well, which is about five miles to the north-west, is a shallow stone-lined well at the foot of a flat granite rock.

The surveyed road is, however, an excellent track, except a sandy stretch beyond Golden Valley, and one beyond Currajong.

From Jackson there are two tracks to Marda—one to the Government tank, and one at Allen's Find.

From both Jackson and Marda there are tracks to Pigeon Rock, where there is a permanent well.

All the tracks and water-holes are marked on the accompanying map (Plate 17).

From Marda an old track goes out to the north-east to Mulline through Chalarie Rocks (small gnamma hole) and Dooling Soak. From Pigeon Rock there is also a track to Chalarie Rocks, through Olby Rock (three covered rock holes).

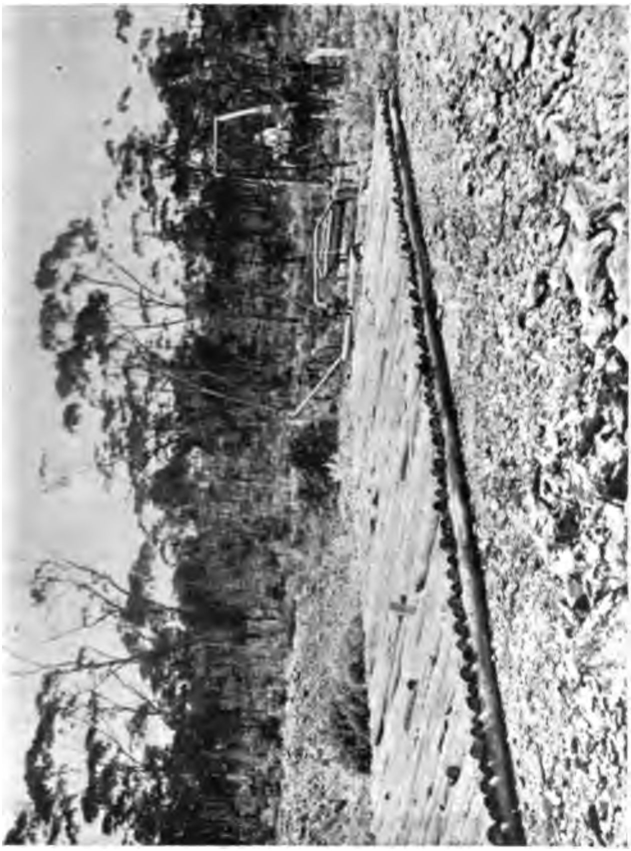


Fig. 29.

Neg. 1352.

Photo: C. S. Honman.

Government tank north of Koolyanobbing.

From Ennuin a very old track goes through the Native Well and passes to the north of Bungalbin towards Mulline.

At Koolyanobbing there is a covered and cemented tank of 50,000 gallons capacity (Fig. 29).

III.—GENERAL GEOLOGY.

The rocks of this country may be roughly divided into three series, viz., granite and greenstones, and sedimentary, and by far the greater portion of the area is represented by granite. With the exception of the superficial deposits of sand, laterite, and alluvium, all the rocks have so far proved destitute of fossil remains, and for that reason, and their lithological resemblance to certain rocks in other parts of the world, they are at present classed as of Pre-Cambrian age. They belong to the same age as all the Eastern Goldfields rocks, and can be classified on the same lines.

The general succession is as follows:-

Recent		Superficial		Laterite. Alluvium. Dry Lake deposits.
Pre-Cambrian (Proterozoic)		Kurrawang Series		Conglomerates. Sandstone. Slates.
	Greenstone Series	Intrusive		Newer Granite. Pegmatite. Porphyry. Amphibolite.
		Sedimentary		Ferruginous quartzite (Jasper)
		Volcanic	Acid	Rhyolite Porphyry. Rhyolite Porphyry Breccia. Quartz Porphyry.
			Basic	Carbonated Ultra-basic rock. Amphibolite. Dolerite. Fine-grained gabbro. Amygdaloidal Dolerite. Ophite and Tuffs.
Archæozoic				Older Granite and gneiss.

Generally, the rocks of the area are composed of an ancient granite complex, containing remnants of a volcanic series which probably originally covered the whole area. Tremendous orogenic movements resulted in severe folding and consequent tilting.

By denudation the geo-anticlinal portions of the volcanic rocks were worn away and the synclinal portions left as remnants in deep folds of the granite complex. The pressures generated by the orogenic movement have resulted in the formation of plutonic granite masses, which have imposed thermal metamorphic effects upon the dynamic metamorphism of the volcanic series.

The volcanic series was originally composed of horizontal sheets of lavas and tuffs, both of acid and basic composition.

The tilted beds have been squeezed and metamorphosed to such an extent as to appear from a superficial examination to be composed of a solid mass of amphibolite and dolerite. Intercalated in the volcanic series are beds of sediments, laid down conformably with the former, probably during a period of volcanic quiescence. These sediments have been, of course, tilted with the rest of the rocks, and are now represented by almost vertically banded ferruginous quartzites.

In the Jackson greenstone belt the amphibolites appear to occupy the margins adjoining the granite, and have probably been formed from volcanic rocks similar to the dolerites and gabbros of Marda, by contact metamorphism.

IV.—DESCRIPTIVE GEOLOGY.

Treating the different rocks individually in their historical order, the first to be described should be the ancient basement which is probably now represented by the many scattered outcrops of gneiss and gneissic granite. The plutonic granite, being of later origin and formed by the absorption of the gneissic basement, will be treated later.

GNEISS AND GRANITE (ARCHÆOZOIC).

The gneiss is most usually found close to the boundaries of the greenstone and forms a border round the greenstone belts, separating the more massive granite from the greenstone. But it is undoubtedly true that the former has in many places broken through the barrier of gneiss and invaded the greenstone, as can be clearly seen around the Koolyanobbing Ranges, where a number of granite dykes occur in the greenstone. On the western contact of the Koolyanobbing greenstone belt the gneissic border can be distinctly seen outcropping about 1½ miles south of Chadwick's Reward Claim. Here the gneiss contains the oval remains of felspars, which look like stretched pebbles in a conglomerate. But the gneissic bands can be seen bending round the felspar giving them a typical eye structure. It has probably been formed by the crushing of a coarsely porphyritic granite.

On the east of the range there is also a fairly wide development of gneiss, some miles in width. To the south-west of Jackson numbers of the large granite bosses have a banded structure, which is parallel to the usual north-north-west strike of the rocks of the Eastern Goldfields.

At Elachbutting Rock alternating bands of coarse and fine-grained granite succeed one another. The coarse bands contain porphyritic crystals of felspar, with their longer axes parallel to the strike of the bands. They have a rough bedded appearance.

The best outcrop of distinctly fundamental gneissic granite showing distinct sharp bands of different texture and giving a banded appearance, suggestive of a sedimentary origin, occurs at the Native Well on the new Southern Cross-Mt. Jackson track. This outcrop is in a direct line with the western contact of the Koolyanobbing Range, and of the western elbow of the Jackson greenstones belt, which also has a margin of gneiss. As opposed to a sedimentary origin for the gneiss it is possible that the banded and gneissic structure has been produced in plutonic granite by lateral pressure, in which case the "eyes" of felspar in the gneiss at Koolyanobbing are accounted for by the foliation of a coarse porphyritic granite.

The large masses of plutonic granite now represented by the frequently occurring bosses and tors and covering large tracts of country were probably formed by the absorption of the gneiss.

GREENSTONE SERIES.

Basic Volcanic Rocks.—Generally speaking the basic volcanic rocks are composed of massive dolerites and fine-grained gabbros, or massive to schistose amphibolites, according as they occur away from or close to the granite contact.

Three belts of greenstone occur in the area, viz.:—

(1.) Extending from Diemels and Die Harty Ranges through Jackson, where a bend in the belt occurs, and passing through the Bungalbin Ranges to the eastern boundary of the Yilgarn Goldfield.

(2.) Embracing the Koolyanobbing Ranges.

(3.) The Ennuin belt, which does not extend beyond 10 miles north of Currajong. Taking the Jackson belt as typical, and which has been examined more particularly, it is described below in detail.

The Dolerites in the Jackson belt are fine-grained, massive rocks and cover large tracts of country. The following is a description by Mr. Farquharson of typical specimens:—

[13914.] Country rock from the Butcher Bird Mine. A somewhat dull, greyish-green, fine-grained rock with a yellowish tinge in the more decomposed portions and showing minute reflecting surfaces and dull green spots.

In section the rock is in great part opaque, grey granular with short and long columnar and platy crystals of a colourless mineral, with high refractive index and birefringence, and referable mostly, if not wholly, to colourless epidote. There are also pale green patches enclosing aggregates of epidote plates, with somewhat opaque rims, occasional curious greyish patches resembling kaolinised felspars, and dark-walled almost skeletal crystals, of which the walls are in great part composed of chloritic scales or with associated epidote. Some greenish grey granular patches usually opaque, and white by incident light, also occur.

In polarised light, the slide is almost wholly of uniform low birefringence. There are, however, occasional short and columnar crystals, some of which are epidote, others probably epidote but closely resembling augite, since optical extinction was indefinite; there are many small plates and platy aggregates of almost colourless epidote and zoisite, occasional areas of almost isotropic chloritic material with associated epidote, in columnar form representing either felspar or augite (probably the latter). There are, moreover, platy crystals of low birefringence which are felspar, and in places can be seen thin columnar or broad lath-shaped and quite opaque crystals projecting into shapeless areas of clear quartz and referable with little doubt to remains of felspar crystals similar to those in some altered dolerites. The alteration of the felspars appears in part to result in the production of kaolin, in part of epidote, but is in all cases sub-microscopical. The forms seen seem to indicate a kind of ophitic (sub-ophitic) structure in the rock. There are some shapeless areas of clear interstitial quartz.

Most curions of all, however, are occasional areas of greyish clear material, which in polarised light and with high powers proves to be distinctly spherulitic in places. There are in some instances clear quartz crystals even with pointed ends and with straight uniform lines in the interior of these areas, and round them is a rim of clear fibrous plates, the plates set at right angles to the rim; beyond these occur either isolated spherulites with well-marked radial extinction, or small aggregates of them in the greyish mass. This latter seems in places to give rise to spherulitic aggregates. In any case, it is not isotropic, but distinctly depolarises and exhibits a wavy extinction. The spherulites and the fibrous fringe, as well as the whole greyish mass, indicate that the mineral is chalcedony and is not a glass. Now chalcedony can appear as an original constituent of the ground-mass of very silicious-porphyritic eruptive rocks or as a decomposition product in all kinds of rocks. It is unlikely, seeing that interstitial quartz occurs in the rock, that it is original, though it is fairly prevalent in small areas in the rock slide. On the other hand, if it is secondary, there must have been cavities in the rock-mass in which it could have been formed and in which the enclosed quartz crystals could have been produced (probably by the action of alkaline silicate solutions). It would appear, then, that either the rock has been subjected to great leaching and decomposition, or has been of a vesicular nature, and the vesicles have become filled. The rock betrays marked evidence of alteration, chemical and mineralogical. The presence of epidote, of chlorite, the loss of part of the optical effects in the slide, and the opacity of the felspars all evidence the alteration, so that the rock in any case is largely the product of decomposition. The sub-ophite structure noticeable in places suggests a dolerite origin. The rock is, in its altered form, difficult to name, but it appears to be most probably an epidotised and chloritised basic igneous rock, probably originally a dolerite.

[13913.] **Between the Marda dam and the Standard Mine.**

An exceedingly fine-grained dark-green rock.

In ordinary light there are numerous small imperfect rods of a green slightly pleochroic scaly mineral and grains of iron ores, in an almost clear but slightly greyish granular mass. In polarised light, the greenish forms are seen to consist mostly of isotropic chlorite associated together with much granular epidote and occasionally with granular calcite. They have the appearance of the columnar felspars that have been partially or wholly chloritised and epidotised, for in some cases portions of the original felspar substance still remain. In addition, there are some indefinitely columnar and platy felspar forms, with characters, however, much obscured. Grains of epidote and calcite are scattered

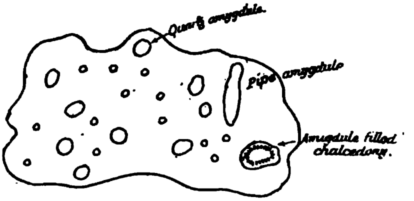
all over the slide, and some shapeless plates of quartz are identifiable. The character of some of the larger greenish chloritic forms suggests an origin for them from hornblende or augite. The rock is much weathered, and indefinitely characterised both mineralogically and structurally, but an indistinct ophitic structure appears to be present.

The rock is classed as a fine-grained chloritised dolerite.

The specimens submitted were as fresh as could be obtained. The determinations, however, sufficiently establish them as dolerite and one as an amygdaloidal dolerite.

The amygdaloidal structure is plainly visible in hand specimens in the field, the amygdules being now filled with quartz. These quartz fillings weather out as perfectly rounded pebbles. The amygdules vary in size from almost microscopic size up to ¼ inch in diameter. The amygdaloidal structure is visible in both the acid and basic rocks. Of the basic amygdaloids the best outcrops are in the vicinity of the Butcher Bird Mine, and the acid representatives occur between Bulgine and Mt. Jackson Trigonometrical Stations. (See Fig. 30.)

Fig. 30.



Showing vesicular structure in decomposed porphyry near Mount Jackson Trig.

A specimen of greenstone from south of the Butcher Bird mine has been described by Mr. Farquharson as a porphyritic vesicular basalt or augite andesite. This rock contains radial spherulitic chorlite, which is a typical component of a vesicular lava flow. An extensive development of this rock may be traced between the more acid lavas and the dolerite, and probably represents a transition from basic to acid flows.

Another interesting variety of the greenstone occurs east of the Marda tank. This has in places a peculiar pisolitic structure and weathers with a roughened spherulitically pitted surface. The size of the spherules are uniform in individual specimens, but vary at different places from pea-size up to ½ inch in diameter. This rock is probably a variolite or ophite and resembles rocks of volcanic in in the Lake Superior region in America, which are named phites" by the Michigan Geological Survey and "variolites" by e United States Geological Survey.

The following is a description of a specimen of tuff associated h the ophites examined microscopically by Mr. Farquharson.

[13938.] Surface outcrops between the Marda Tank and the ndard Mine.

Specimens vary from a minutely grained almost flinty type with al rounded quartz nodules, through a nodular flinty type to a coarse- ined greenish-grey but still almost aphanitic rock.

In section, the rock proves much too weathered for definite deter- ation, having been altered by exposure as a capping, but a few ts can be made out. It appears to be of fragmental origin. There small angular pieces of kaolinised felspar, grains of epidote occur- sporadically and in aggregates, opaque grey granular forms of tful character but in part chloritic and kaolinic, small grains of rtz—in one case almost hexagonal—and occasional peculiar rounded retionary forms. In places are what appears to be the remains of ge completely weathered crystals. There is an almost uniform low fringence throughout the slide almost amounting to isotropism. In e finer grained type the slide is a minutely grained yellowish-grey s of almost isotropic character; but here and there, especially in nodular variety, are rounded quartz patches resembling quartz les, and occasional angular or fragmental patches of quartzose e which probably represent completely weathered felspar frag- nts. The nodular variety also exhibits strings of yellowish green ritic material sometimes surrounding smaller nodular forms.

The structure of the rocks is very indefinite, due to advanced altera- n, but it appears to be of fragmental origin, and is put down with t as a much altered, fine-grained volcanic tuff.

Between Marda and Jackson and to the north of Curragibbin nometrical Station the greenstones are more basic. In hand imens they are a fine-grained dark green rock which under the roscope is seen to be a gabbro or basic dolerite. This has the e field relations as the amygdaloidal dolerite and is probably a re basic variety of the same volcanic series.

CARBONATED ULTRA-BASIC ROCK.

In the Great Unknown Mine at Marda the country rock is a nated rock which corresponds in composition with a peridotite. e carbonated peridotites of Kalgoorlie have been so far recog- d as being of intrusive origin. The presence in the carbonated k at Marda of a banded quartzite cannot, however, be reconciled an intrusive origin for this rock, especially as a shear zone in the k is later than the banded quartzite. Owing to the sedimentary n for the quartzites put forward later this carbonated rock is arently interbedded with a volcanic sediment (viz., banded rtzite), and therefore must be a volcanic rock itself, therefore a nated ultra-basic lava flow. This view I think is most con- nt with all the facts discovered in the district.

An analysis of the country rock of the Great Unknown Mine and the shear zone in which the quartz occurs gives the following composition:—

	(1.)	(2.)
SiO_2	41·95	33·04
Al_2O_3	7·05	8·63
Fe_2O_3	·31	·29
FeO	11·22	13·22
MnO	·26	·16
MgO	16·97	14·99
CaO	·64	·77
Na_2O	·10	·14
K_2O	·83	·76
H_2O —	·06	·08
H_2O +	3·66	3·49
TiO_2	·32	·71
CO_2	16·20	13·07
P_2O_5	·15	·10
FeS_2	·09	10·21
Cr_2O_3	·34	·18
V_2O_5	trace	·01
C	*Nil*	·12
	100·15	99·97
Sp. Gr.	2·91	3·09
Analyst	E. S. Simpson	H. Bowley.

(1.) G.S.M. $\frac{1}{60}$. G.S.L. 6761D.—Country rock of Great Unknown, Marda.

(2,) G.S.M. $\frac{1}{77}$. G.S.L. 6762D.—Shear zone of Great Unknown, Marda.

The presence of chromite is confirmed by the analysis giving .34 per cent. of Cr_2O_3.

Amphibolite.—At Jackson all the country rock with the exception of the quartzites and ferruginous quartzites (jaspers) is composed of fine-grained amphibolite of varying textures, the coarsest being in the minority and of medium grain.

The amphibolites at Jackson have the same field relations to the ferruginous quartzites (jaspers) as the dolerites have at Marda. The quartzites are less contorted and more ferruginous than at Marda.

Owing to their proximity to the granite to the west, their relations to the banded ferruginous quartzites (jaspers) and their variation in texture, the amphibolites are most probably derivatives of the dolerites by metamorphic action and uralitisation. There is no evidence of an intrusive origin for the amphibolites.

ACID VOLCANIC ROCKS.

These consist of different kinds of porphyry, which vary from fine-grained almost felsitic porphyry to a coarse-grained rhyolite porphyry.

Three developments of porphyry occur at Marda, one on the rthern boundary of the greenstone (see Fig. 31); one on Allen's al; and one in the Mt. Jackson ranges.

Fig. 41.

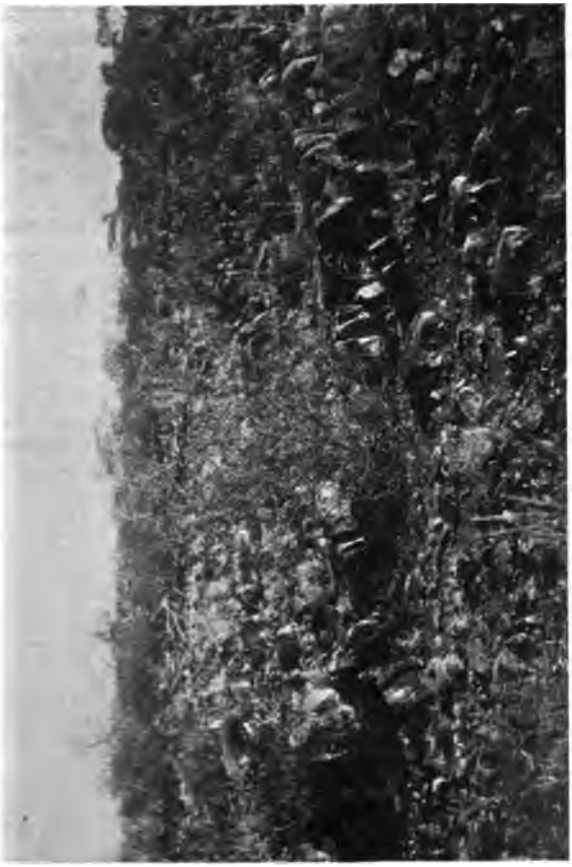


Photo: C. S. Honman. Neg. 1355.

Outcrop of rhyolite porphyry north of Butcher Bird Gold Mine.

The northern occurrence consists of a large development of lite porphyry which is in places decidedly fragmentary, and changes to the north into a pink felspar porphyry very ar to the felspar porphyry at Binduli near Kalgoorlie.

At Allen's Find the country rock is very decomposed and its position is not clear, though it is an acid rock of some descrip- n and contains remains of porphyritic felspar.

The southern occurrence of porphyry outcrops three miles th of the Marda Tank, and is of much more limited development an the northern occurrence. This porphyry is almost felsitic, showing faint outlines of felspar phenocrysts, and also rounded phenocrysts of quartz. In hand specimens it is a pale pink colour to almost white. Interbedded in it there occur a number of parallel bands of ferruginous quartzite (jasper) similar in every respect to the quartzites in the basic series, and striking parallel with them. This is significant as correlating the porphyry with the basic volcanic rocks and placing them also as volcanic rocks, viz., acid lavas. This is supported by the fragmental bands in the Rhyolitic porphyry north of the Butcher Bird No. 1

Associated with the southern band of porphyry in a gully between Bulgine and Mount Jackson Trigonometrical Stations, there occurs a decomposed rock which has the appearance of being derived from, and is on the same strike, as the felsitic porphyry on the southern slope and summit of Bulgine Trigonometrical Station. This decomposed rock contains perfectly round inclusions of quartz which in distribution and appearance are similar to the vesicles formed in a lava flow, or slag, and have exactly similar characteristics as the vesicles in the vesicular basalt near the Butcher Bird. Some of the cavities instead of being completely filled with quartz, have a concentric ring of quartz with a hollow centre, the growth of quartz being from the periphery of the cavity inwards as in Fig. 30, which is distinct evidence of amygdaloidal structure. An analysis of a weathered specimen of the felsitic porphyry gives the following results:—

G.S.M. $\frac{1}{62}$, G.S.L. 6763D.

SiO_2	81·00	80·05
Al_2O_3	15·09	9·73
Fe_2O_3	0·25	1·72
FeO	0·20	0·18
MgO	0·10	*Nil*
CaO	*Nil*	0·83
Na_2O	0·04	2·19
K_2O	0·14	4·43
TiO_2	0·61	..
P_2O_5	0·07	..
CO_2	*Nil*	..
SO_3	trace	..
MnO	*Nil*	..
H_2O —	0·20	..
H_2O +	2·92	..
	100·62	

Analyst: .. .. D. G. Murray.

(1.) Weathered felsite porphyry from Creek between Bulgine and Mount Jackson Trigonometrical Stations.

(2.) Quartz porphyry Mount Haughton, Michigan, U.S.A.

Although No. 1 specimen from Marda is much weathered, it can be seen that its composition is sufficiently close to No. 2 (an ndoubted felsite porphyry of effusive origin) to establish its identity as such, especially with supporting field evidence.

This is important on account of the amygdules only being found in the weathered rock. The low percentage of soda and potash in the Marda rock (No. 1) may easily be accounted for by weathering. It is therefore evident that these rocks represent a series of acid amygdaloids, lavas and tuffs.

The rhyolite porphyry, of which there is a prominent outcrop north of the Butcher Bird Mine, is a dark bluish-grey rock showing numerous white phenocrysts of felspar in a dark aphanitic ground mass. In places it is a distinct breccia which is, however, never very coarse. On weathered surfaces the fragmental character of certain bands is obvious.

About four miles north of Marda, on the Pigeon Rock track, there is another bold outcrop of a banded rhyolite porphyry with a selvage of black glassy rhyolite. In hand specimens it looks like a black chert, but its field relations place it as a phase of the rhyolite porphyry.

An analysis of the rhyolite porphyry gives the rock the following composition:—

G.S.M. $\frac{1}{59}$. G.S.L. 6760D.—Rhyolite porphyry 20 chains north of the Butcher Bird Mine.

SiO_2	69·93
Al_2O_3	13·92
Fe_2O_3	1·04
FeO	2·80
MnO	·26
MgO	1·02
CaO	2·21
Na_2O	3·87
K_2O	3·18
H_2O —	·04
H_2O +	1·16
TiO_2	·28
CO_2	·16
P_2O_5	·15
FeS_2	·02
	100·04
Sp., Gr.	2·72
Analyst	E. S. Simpson.

Unfortunately, owing to the scarcity of outcrops and exposures dips, no measurements of the lava beds and dips can be given, ugh the dips of the jaspers should correspond with them.

The dips are, however, roughly vertical in the southern porphyry and owing to the much greater horizontal distribution of the northern porphyry the dips of the latter are probably fairly shallow.

FERRUGINOUS QUARTZITES (JASPERS).

The ferruginous quartzites occur exclusively in the greenstone series and appear to be interbedded with fine-grained greenstones and felsite porphyry. These rocks are locally known as "jaspers" by miners and prospectors.

Their extensive and continuous distribution in the greenstone belts is brought out by the mapping shown on Plate I. This shows only the most prominent exposures and there are many minor exposures which, owing to the broad nature of the work, could not be delineated.

The most prominent exposures are in the Die Harty Ranges, east of Pigeon Rock, at Jackson and Marda, and at Bungalbin. Exposures can be traced between these points and are sufficient to show the complete continuity of the bands.

The "Jaspers" also form a backbone to the Koolyanobbing and Ennuin greenstone belts.

Dips are determinable in most of the outcrops and show the steep angle at which the rocks are tilted, the lowest recorded dip being 35deg. east at Athlone, where an anticlinal formation can be seen about a mile north of the workings. Around Pigeon Rock the dips are mostly to the west at varying angles; at Mt. King to the west; the Die Harty ranges and Windarling Peak to the south; at Jackson to the east with a much gentler dip; and at Marda the beds are almost vertical with a general inclination to the north. They appear, therefore, to form a huge syncline pitching to the east.

The quartzites are in all cases extremely evenly banded and considerably contorted in places (Figs. 32 and 33). They are composed of alternating bands of ferruginous and quartzose material. The ferruginous bands are composed of hematite and magnetite in varying proportions and sometimes limonite. In hand specimens they are composed of alternating bands of light and dark colour, varying from bluish-black, through all shades of red to white (Fig. 33).

Three chief varieties occur according to which coloured bands predominate—

(1) Blue-black banded variety;
(2) Red banded variety;
(3) White banded variety.

The blue-black and white banded varieties are most prominently represented near the granite contacts at Jackson and around the inlier at Pigeon Rock.

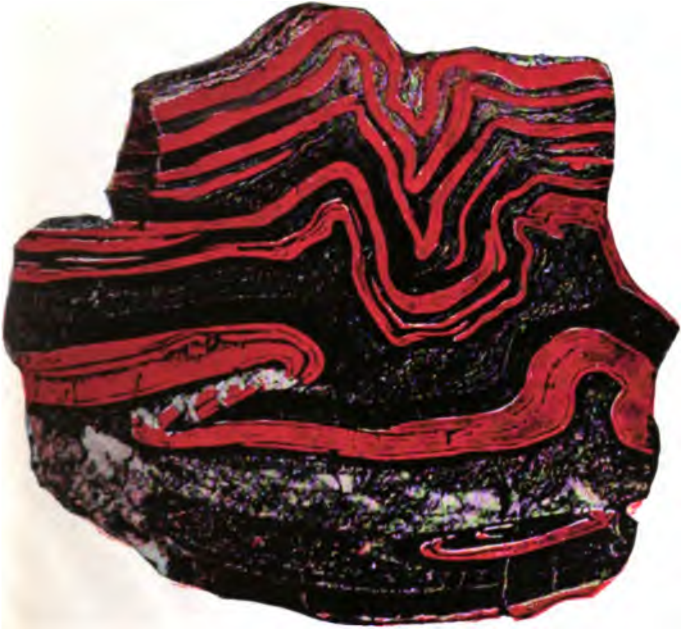


Photo: R. H. Irwin. Neg. 1321.

Fig. 32.

Contorted Jasper, ½ mile west of Great Unknown Gold Mine, Marda.

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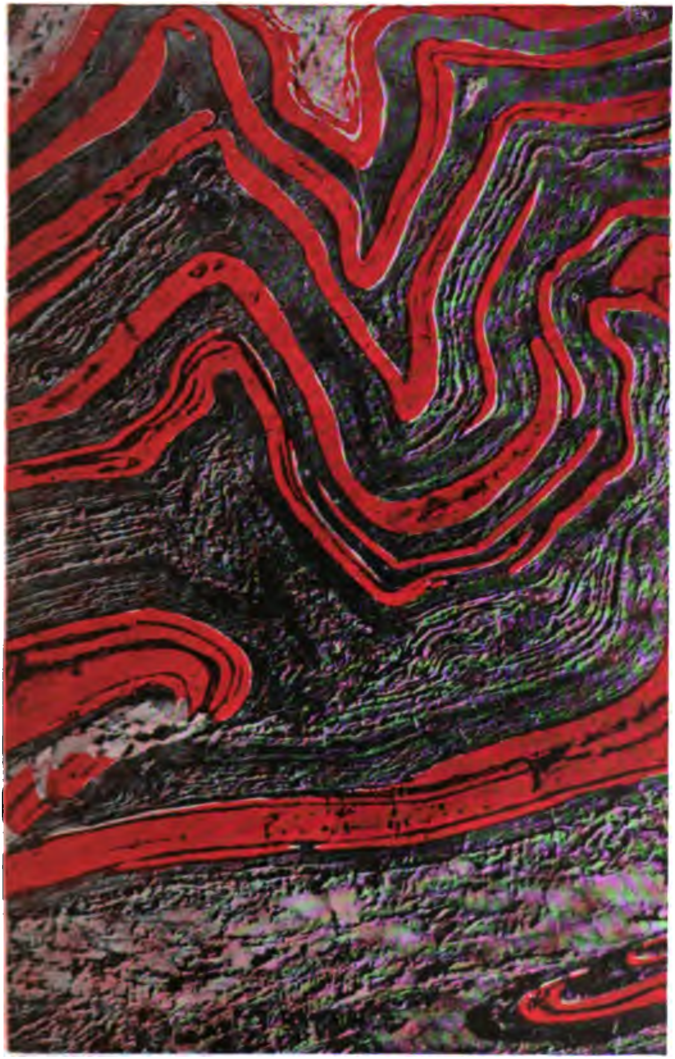

Photo: R. H. Irwin. Neg. 1322.

Fig. 33.

Contorted Jasper, ½ mile west of Great Unknown Gold Mine, Marda.

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The red banded variety, which commonly has a brilliant vermilion hue. occurs at Marda and Bungalbin where huge cliffs showing several hundreds of feet of vermilion quartzites occur among the ranges.

There is a cherty variety of "Jasper" which is not evenly banded, but appears to be a secondary deposition of quartz along cracks and fissures in the contorted banded rock. This cherty material is often accompanied by quartz veinlets.

The ferruginous quartzites (jaspers) of Marda are apparently of sedimentary origin. But rocks of similar character have, in other districts, been described as shear zones in greenstone, and in the southern portion of the Yilgarn Goldfield, Mr. Blatchford favours such an origin for certain ferruginous quartzites occurring there. These, however, according to Mr. Blatchford's report * have characters distinct from the Marda quartzites.

The siliceous and ferruginous character of the quartzites in general is probably of secondary origin and such an impregnation would be found to occur both along lines of shearing or schistose zones and sedimentary beds; in fact, along any rock capable of providing a free circulation for underground waters. If such is the case the resulting rock, whether an impregnated shear zone, schist or sediment, would be hard to distinguish in hand specimens.

The banding of the Marda quartzites (jaspers), however, appears to me to be too uniform and regular to be caused by shearing or schistosity, and has a strong resemblance to that of sedimentary beds, both in appearance and structure, for example, the anticline occurring north of the Athlone leases. Their contact with both the massive and schistose greenstones is invariably perfectly sharp, especially at Marda. At Jackson, however, when a schistose wall occurs it sometimes has an appearance of being either a schist impregnated with iron oxides or *vice versa,* a ferruginous quartzite impregnated with hornblende.

The Marda quartzites have also been subjected to all the dynamic forces that have acted on the greenstones, such as fissuring and shearing. In the Great Unknown mine at Marda a shear zone in the greenstone actually passes through the banded quartzite, and has formed a shear breccia composed of fragments of banded quartzites.

The following chief characteristics of the Marda "Jaspers" strongly suggest that they are of sedimentary origin:—

(1.) The remarkable and persistent evenness of the banding, many hundreds of feet in thickness, more even than known shear zones and just as even as any series of sediments.

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* Bull. No. 63.—The Geology and Mineral Resource of South Yilgarn, by T. Blatchford.

(2.) The proved continuous occurrence of the evenly banded structure for 70 miles in length in the greenstone belt, and perhaps much longer. This is a structure undoubtedly produced by sedimentation, a process which takes place under such uniform conditions as would produce a great persistence of even banding.

(3.) Variation in dip from 30deg. to vertical and the presence of anticlinal folds.

(4.) The association with volcanic rocks at Marda with which they are interbedded. It would be most unusual to have a big development of volcanic rocks without sediments of some kind interbedded with them. The ferruginous character of the quartzites would be consistent with volcanic sediments as indicating an original basic composition.

(5.) If the "Jaspers" represented shear zones then owing to their great length they could only have been formed by regional movements. In which case it would be only reasonable to expect to find an equivalent effect on some of the gneisses and granites which are devoid of anything approaching a similar character. But the porphyries in the greenstone series which have a very similar chemical composition to granite do contain banded quartzites.

(6.) Distortion, faulting and brecciation of the quartzites by the same earth movements which have formed shear zones in a direction across their strike showing that the quartzites existed before the shear zones were formed in the rocks.

(7.) The general ferruginous character of the beds would be accounted for by the basic composition that volcanic sediments usually have when associated with basic volcanics. It is interesting to note that the quartzites occurring in the porphyries are non-ferruginous, which is consistent with the above views.

The other belts of greenstone have not been examined in the same detail as the Jackson belt, but generally they are composed of fine-grained greenstone and jasper.

The Koolyanobbing belt is about five miles wide and over 30 miles long striking in a north-west direction. It is characterised by the usual hard backbone of ferruginous quartzites which form prominent ridges for its whole length.

INTRUSIVES.

The intrusives at Marda are made conspicuous by their absence. In fact away from the granite contact no decided intrusive rocks were met with, unless some of the coarse amphibolite outcrops represent later intrusive masses, but, unfortunately, no field evidence could be found of the relation of such isolated coarse-grained amphibolite to the fine-grained greenstone.

In the old Mt. Jackson Proprietary workings at the 100ft. here occurs what appears to be a coarse amphibolite dyke, ing to the decomposed nature of the ground its relations were lear. Not having well-defined walls it might be a coarser of the fine-grained amphibolite.

In the greenstone belts I saw no undoubted intrusive dykes of tes: all the dolerite outcrops seemed to be part of the volcanic

In the granite country, however, opposite the 60-Mile post on Rabbit Proof Fence and about one mile on the south of Geer- Rock, a dyke of fine-grained dolerite, about two chains wide, almost east and west across the track from Elachbutting. At thern foot of Geeranning Rock another dyke occurs, also east and west, composed of a coarse-grained amphibolised This has fine-grained margins and an epidotised phase on de. They were the only basic dykes met with in the granite

Near the granite contact intrusives of pegmatite and granite frequent occurrence, and in most cases have a strike parallel the contact. Near the northern contact of Koolyanobbing- stone there are numerous granite intrusions, which have an ilar trend and of considerable width in places. It is on the of one of these granite intrusions that the reefs of the Rain- occur (see plate), and in the greenstone schists into which ranite is intrusive there are bands of felsitic porphyry asso- with the quartz reefs.

On the north-east contact of Koolyanobbing Range there are intrusive dykes of granite, also east of Mt. King, and south of Jackson.

THE KURRAWANG SERIES.

The rocks of the series which is correlated with that at Kurra- rest unconformably on the ancient greenstones, and are com- exclusively of slates, quartzites, and conglomerates of dif- grades and textures. These beds are sporadically, though distributed over the greenstone belts, and represent rem- of a series that once covered a much greater area.

The chief exposures are on the northern fall of the Mt. Jackson at Marda (see Fig. 34), and north of Marda running east west from the 14-Mile on the Ularring Road, through the old William, and thence between Allen's Find and the Great Un- Not sufficient outcrops occur to correlate the individual of the series. Isolated outcrops show one class of bed exposed at a time, and therefore no accurate section can be drawn of the series.

Fig. 34.

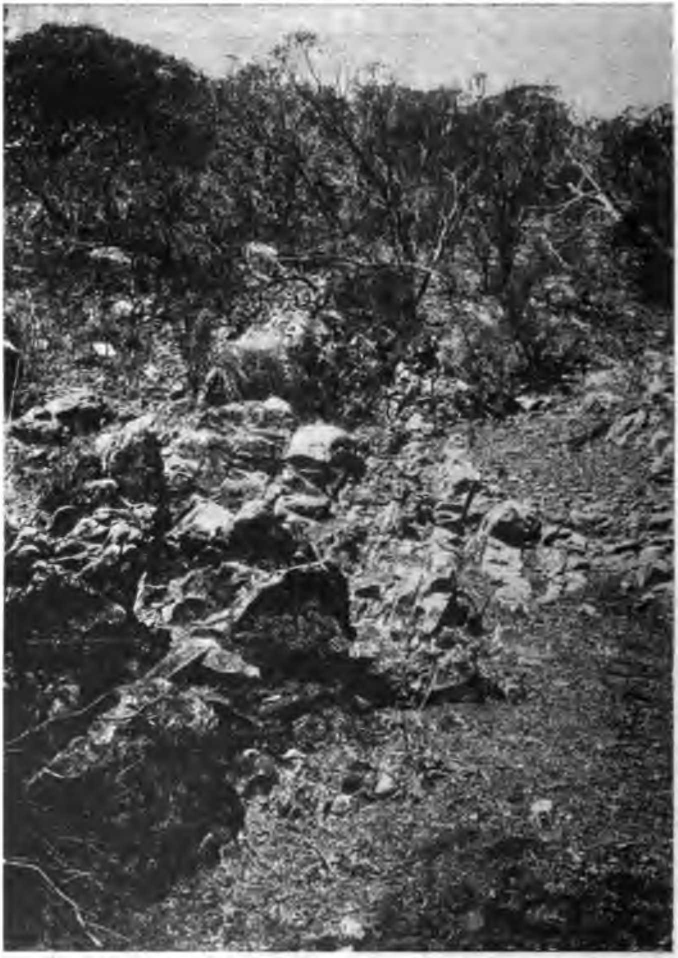
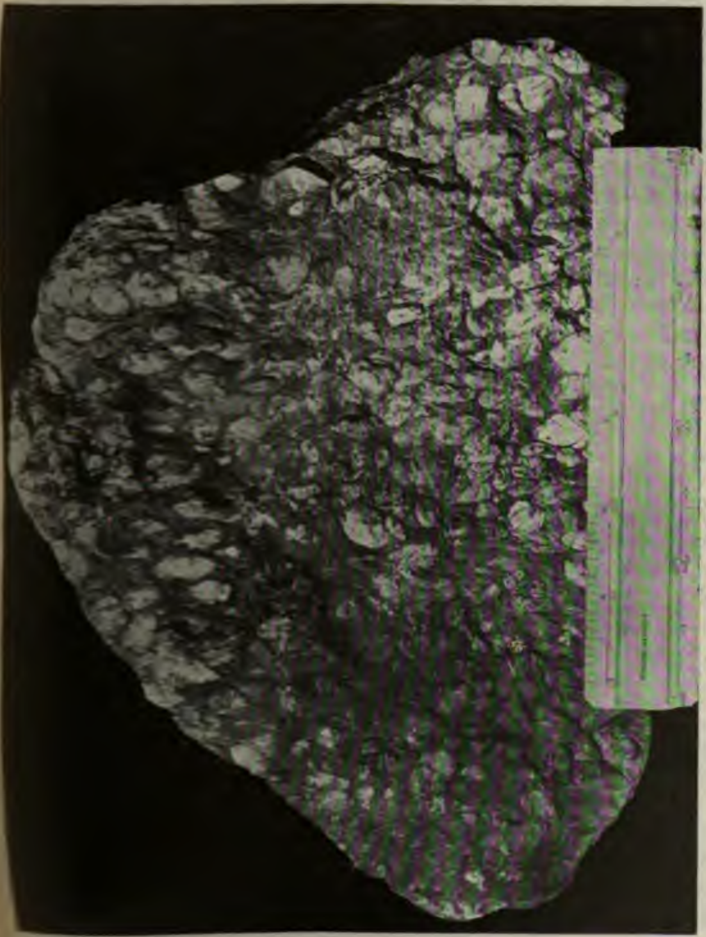


Photo : T. Blatchford. Neg. 1323.

Sediments in creek between Bulgine and Mount Jackson Trigs.

But it is certain that it consists of alternating beds of conglomerates (see Fig. 35), sandstones, and slates. Other outcrops occur on Victoria Trigonometrical Station at Jackson. In a preliminary statement, written for the annual report of 1914, the Victoria Trig. outcrop was correlated with the banded quartzites outcropping around it, but later researches show that these beds belong to the Kurrawang series and are resting on the quartzites (Jaspers). Their association with the older quartzites is merely a coincidence.

Plate IX.



Specimen of conglomerate from south of Allen's Find.

Photo: T. Blatchford.

Neg. 1304.

This outcrop shows distinct current bedding. Their strike is north-east and they are sheared in a north-west direction. In hand specimens it is compacted friable quartzite. The following is a description by Mr. Farquharson:—

[13939.] Victoria Trig., west of Jackson Townsite:—

A quartz rock varying from white in colour to yellowish white, and a hand specimen consisting of angular or irregularly banded grains of quartz. The yellowish variety has a somewhat friable structure.

In section, the rock consists of large and small interlocking an irregularly outlined grains of quartz, the boundaries clearly marke by dust particles, and with a small amount of silicious cement develope The structure of the rock is that of an Itacolumite, and the rock is quartzite formed from loose grains of quartz compacted by pressu and to a certain extent by development of secondary quartz. It is c clastic origin.

Another outcrop very similar to that at Victoria Trig., but c coarser grain, occurs 2¾ miles north-east of Buddarning Trigon metrical Station. This is probably a continuation of the Mard occurrence.

West of Pigeon Rock, there is a belt of conglomerates strikin in a north-west direction. This can be seen outcropping on th Yarbu track and on a hill to the east-north-east of Yarbu. In th latter place the adjoining bands of sediments are very much indu ated and are in places impregnated with tourmaline.

At the northern extremity of the Ennuin belt of greenstone an about five miles north of Currajong there is an outcrop of indurate sandstone that greatly resembles the current bedded rock at Vi toria Trig., and probably representing another outlier of the Kurra wang series.

The proof of unconformity is based on the following facts:–

(1.) Presence in the conglomerates of pebbles of bande quartzite and vermilion quartzites (Jaspers) and o quartz porphyry, which are identical with the rocks o the greenstone series.

(2.) Great lithological difference between the beds of the tw series.

(3.) Actual exposure of the younger series resting on th upturned edges of the older series with the beds o either series dipping in opposite directions. This ca be seen on the western spur of the Bulgine Trigono metrical Station, three miles south of Marda Tank.

These beds have been undoubtedly laid down in running wate the pebbles being well rounded and such as would be found in th lower reaches of a large river.

An analysis of a quartzite from the creek bed between the Mt Jackson and Bulgine Trigonometrical Stations shows the followin composition:—

G.S.L. 7470D.

SiO_2	86·96
Al_2O_3	10·24
Fe_2O_3	·82
CaO	trace
MgO	·09
$H_2O +$	1·96
$H_2O -$	·06
	100·13
Sp. Gr.	2·65
Analyst	**H. Bowley.**

The conglomerates at Marda are not crushed like those at Kurrawang, near Kalgoorlie. This is probably owing to their occurring in a zone in which the older series strikes east and west, and so offers sufficient resistance to protect the later series from shearing forces.

Both Messrs. Maitland and Blatchford, who made an inspection of the area towards the end of the field season, were struck with the resemblance of the conglomerates to the Nullagine series in the Pilbara Goldfield.

In the Kurrawang series some interesting nodules occur, which are chiefly spherical in shape and reach up to three inches in diameter. They are mostly composed of flinty material and have apparently grown from a nucleus. There are also concretions of calcite which take most fantastic shapes, and have a form so symmetrical as to suggest their derivation from fossil remains. These flint and calcite nodules occur near the contact of the older and younger rocks and in the younger series.

RECENT DEPOSITS.

The superficial deposits consist of the laterite cappings to the more decomposed portions of the rocks of the highlands and plateaux. The highest portions of the ranges consist of hard, unweathered rock, while the laterite chiefly covers the foothills of the greenstone ridges, and large areas of the granite plateau.

Amongst the ranges there are extensive deposits of alluvium, and the plains are covered with sand for many square miles without the sign of an outcrop.

It is not known to what depth the alluvium extends in the lake country. It is probable, however, except where the lakes hug the greenstone belts that many hundreds of feet of alluvium exist. Close to the ranges the lakes are shallow, bed rock often corresponding with the surface of the lake. This is probably due to the migration of lakes described by Mr. Jutson,* and only extends for a short distance from the shore towards which the lake migrates.

No deep leads or auriferous alluvial patches have been discovered in the Jackson District, though there is no reason why they should not exist.

V.—STRUCTURAL GEOLOGY.

FOLDING.

The broader structural features of the district are brought out by an accurate delineation of the ferruginous quartzites (jaspers), showing the dips of the beds where possible. This shows that there are a series of closely compacted folds where the dips are very steep. At Athlone, Buddarning, and Windarling

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* Bulletin 61, G.S.,W.A., p. 156.

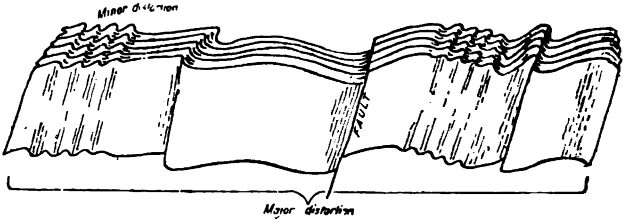
Peak the dips are from 35° to 45°, showing that the folding was less intense inside this area. At Wundarling Peak the rocks dip to the south, and at Athlone and Buddarning to the north-east, hence forming a syncline pitching to the south-east. North of Pigeon Rocks shallow dips are again recorded dipping to the west, showing that the beds are less tilted in that locality also.

DISTORTION.

The jaspers have been distorted by pressure exerted parallel to their strike. This effect is always greater when the beds strike east and west than when they strike north and south. This distortion takes place on a large scale, resulting in a sinuous course being given to the beds over some miles along their strike. This is accompanied by fracturing and faulting. On a minor scale the distortion can be seen even in hand specimens (see Figs. 32 and 33).

The following diagram is a rough representation of the distortion in the ridge of Jaspers at Marda on a number of leases known as the Bergoose Group (Fig. 36).

Fig. 36.



Diagrammatic sketch of contortions in the Bergoose jaspers, Marda.

FAULTING.

Major faulting has taken place at Marda, and a series of major steps faults appear to have taken place at Koolyanobbing.

At Marda the principal major fault passes through a break in the greenstone ridges east of the 10-mile soak on the new Southern Cross track. This break is in line with the course of the undoubted rupture in the Mt. Jackson ranges passing through Boondine to the south-west of Mt. Jackson Trigonometrical Station. Further, this is in the same line as a break in the Rhyolite Porphyry west of the Butcher Bird Mine. Owing to a shortening of the width of the greenstone west of the fault line and a displacement of the south-dipping Jaspers to the south the fault is probably an overthrust from the west. This would result in a narrowing of the synclines and a widening of anticlines west of the fault line, which is what actually occurs (Fig. 37).

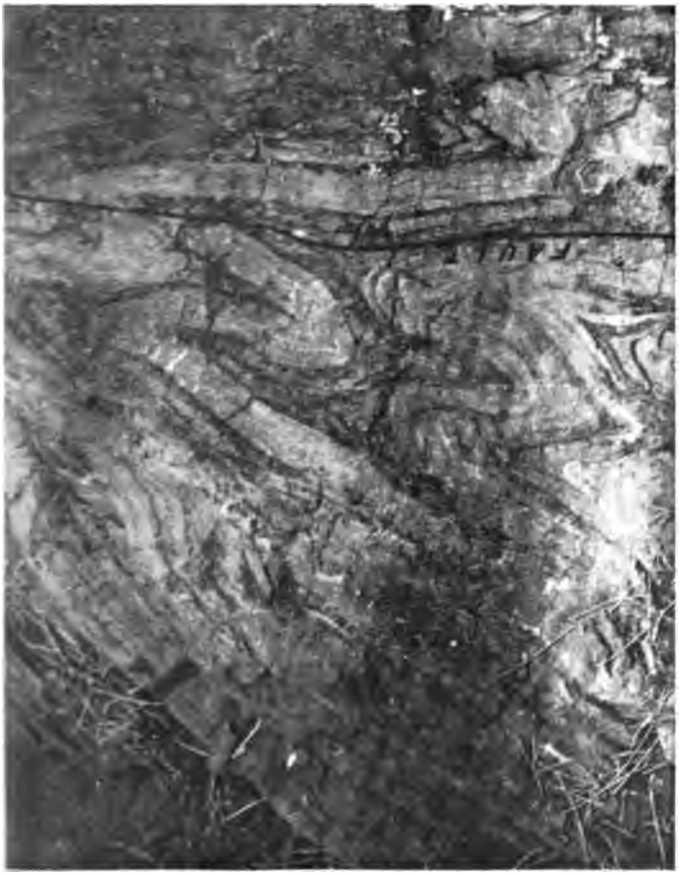


Photo: C. S. Honman. Neg. 1353.

Contorted jasper half mile west of the Great Unknown Gold Mine, Marda.

Faulting on a minor scale is very common in the whole field see Fig. 37), some very good instances of step faulting occurring at Jackson, where a quartz reef can be seen faulted twice with a total displacement of 58 feet within a distance of one chain.

Of the minor faults, two kinds are observable:—

(1) Reversed Dip Faults striking north-east and at right angles to the schistose structure of the region.

(2) Strike faults parallel to the schistosity. The latter type of faulting is not easily seen, as the fault plane becomes confused with planes of shearing. It is generally accompanied by slickensiding.

In the two principal mining centres of the district the structural features are quite distinct, chiefly owing—

(a) to the difference in strike of the rocks in the two centres, and

(b) to the greater metamorphism that has occurred at Jackson, owing to its proximity to the granite contact.

Since the rocks at Marda strike practically at right angles to the shearing and foliating forces, they have been protected to a great extent from those forces and still retain their original structures, but the strains set up have resulted in the formation of an irregular system of fractures.

At Jackson, owing to the line of least resistance, viz., the bedding, corresponding with planes along which shearing and foliation took place, the fissuring has had a longitudinal trend not very far from parallel with strike of the schists.

SHEARING AND FOLIATION

is characteristic of the country close to the granite contact, but towards the centre of the belts the schistose structure is practically absent, except for local shear zones such as occur in the Great Unknown Mine.

PLANES OF PARTING (HEADS)

are very well defined in the Marda rocks, large blocks of stone being easily separated from the massive greenstones owing to the presence of two well-defined series of parting planes.

VI.—ECONOMIC GEOLOGY.

GOLD.

Although the discovery of gold at Jackson was first officially reported as late as 1894, this centre is situated only 40 miles north of Ennuin, where Mr. Harry Anstey's party in 1887 made the first sensational discovery of the precious metal in the eastern goldfields of Western Australia.

The official report on Jackson showed that in October, 1894, two mines had started operations, and that the Nil Desperandum had 150 tons of ore at grass from a number of reefs on which an incline shaft of 46 feet deep and 60° underlay, and a vertical shaft 72 feet deep, had been sunk. These are probably the original workings of the Mt. Jackson Gold Mines, Ltd. One mile north of the Nil Desperandum the Victoria gold mine had a main shaft down 70 feet on an easterly dipping reef, besides three prospecting shafts, and had 50 tons of ore at grass.

At the end of 1895 an official report stated that a new centre had been opened up at Mt. Jackson, and that a battery was in the course of erection. In that year it supported a population of 60 people.

Warden Victor Black, in 1896, reported that the development at Mt. Jackson had been remarkable, and that the population had reached 120 people. In that year a new track was cut from Southern Cross to Jackson.

A quiet year was experienced at Jackson in 1897, though crushings were averaging over an ounce to the ton. For reasons not stated the work was temporarily suspended in 1900, and exemption granted the following year. In 1902 the mines were reported to be again working vigorously, and consistent returns were obtained until 1907, from when mining has been almost extinct.

A revival took place in the district in 1910 following on the discovery of payable reefs 10 miles east of Jackson, at Marda, since when, in spite of poor crushing facilities and other difficulties attendant on its isolated position, Marda has supported a number of prospecting parties who have met with varying degrees of success. Some of the shows now opened up show great promise.

Jackson and Marda, though both occurring in the same belt of greenstones, are essentially different in geological characteristics. In both centres the ore deposits may be divided into—

(1) Quartz reefs,
(2) Ferruginous quartzite lodes.

By far the most important are the quartz reefs, on the successful working of which the future prosperity of the field will depend. At Jackson the country rock is almost universally composed of amphibolite schist striking north-north-west, and the quartz reefs appear to follow definite trend lines.

At Marda the country rock consists of massive volcanics ranging from quartz porphyries to dolerites and ultra-basic rocks, whose strike is almost east and west, and in which the reefs have no regularity in strike or dip.

JACKSON CENTRE.

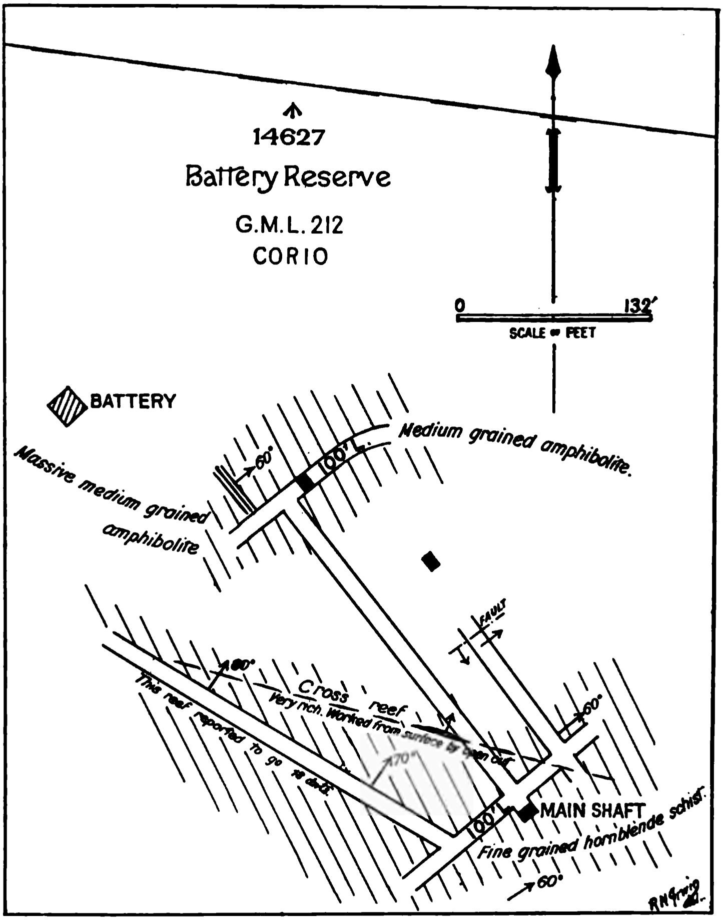
This centre occurs on the western boundary of a large greenstone belt extending from Diemels to Bungalbin. The principal workings are situated a mile to the east of the granite contact. There are two principal series of reefs represented:—

(1) Striking north-west and dipping east.
(2) Striking north and dipping west.

Both have been worked, but the principal workings occur on the first class of reef. Besides these two there is on the Mt. Jackson Gold Mine an east-and-west reef dipping north, which crosses the north-west and south-east reefs, and is said to have been very rich. All the reefs occur in amphibolite schist, and are associated with ferruginous quartzite, but in what relation to the latter cannot be seen in any of the workings, except that in the Associated Mine the reef appears to be deflected by the footwall of the ferruginous quartzite, showing that the reefs are younger than the banded quartzites (Jaspers), which, of course, they must be if the latter are of sedimentary origin.

Faulting on this field is due either to overthrusting from the north or normal faulting to the south. There is not sufficient evidence to show which. Hence westerly dipping reefs are displaced to the left and easterly dipping reefs and ferruginous quartzites to the right. This may be taken as a rule for the district in locating the displaced continuation of a reef.

Fig. 38.


14627
Battery Reserve
G.M.L. 212
CORIO
0
132'
SCALE IN FEET
BATTERY
Medium grained amphibolite.
Massive medium grained amphibolite
60°
100'L.
FAULT
80°
Cross reef
Very rich. Worked from surface by open cut.
This reef reported to go to depth.
70°
60°
100'
MAIN SHAFT
Fine grained hornblende schist.
60°

Sketch plan of 100ft. level, Mt. Jackson Gold Mines, Ltd., G.M.L. 2752.

As all the mines are closed down, and only the upper levels accessible, only such descriptions can be given as the circumstances would permit, and are therefore necessarily incomplete.

Mt. Jackson Gold Mines, Ltd.—This company owned at different times G.M.Ls. 212, 217, 233, 397, 462, 658, and 659. The principal workings are on G.L.L. (212) 2752. All the workings below 100ft. level were under water. Fig. 38 is a sketch plan of the 100ft. level. There are no records of the workings below 100 feet.

The country rock is a fine-grained to medium-grained amphibolite schist, with foliation planes striking north-north-west parallel with the ferruginous quartzites and dipping 60° east. From the main cross-cut on 100ft. level three drives running north-west show roughly parallel reefs dipping 60°-70° north-east. About 50 feet north-west of the main shaft in the main drive an east-and-west reef dipping north cuts the north-west reefs. This cross reef has been stoped to the surface, and is said to be very rich.

The Battery on this lease was taken over by the Government in 1912 and crushings put through for the prospectors at Marda until the Butcher Bird mill at Marda was subsidised in 1914.

The following are the gold returns of this mine taken from the statistics of the Mines Department:—

Table showing the Yield of the Mt. Jackson G.M.

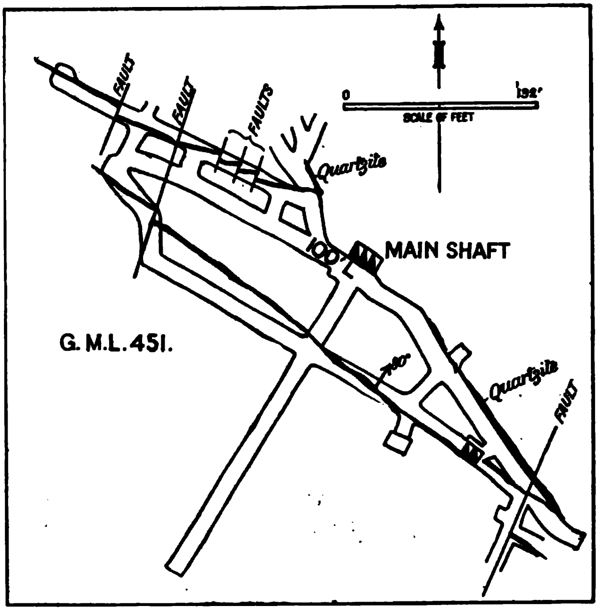
Year.	Ore treated.	Gold therefrom	Silver.
	tons.	fine ozs.	fine tozs.
Prior to 1897	1,514·00	720·06	..
1897	361·00	286·52	..
1898	1,255·00	716·66	..
1899	4,252·00	2,963·83	..
1900	2,155·00	1,219·42	..
1901	..	*10·17	..
1902	..	..	..
1903	..	† 449·86	..
1904	7,844·00	5,723·95	998·00
1905	5,390·00	3,329·09	997·50
1906	1,820·00	597·27	50·00
1906	1,992·00	1,045·99	..
1907	2,514·00	2,251·26	259·78
1908	100·00	31·53	..
1909	150·00	88·02	..
Total ..	**29,347·00**	**19,433·63**	**2,305·28**

* From plates. † By cyaniding.

Associated Mt. Jackson Gold Mines, Ltd., G.M.Ls. 246, 450, 451, 459, and 460.—The principal workings are on G.M.L. 451, but only the 100ft. level was accessible for examination. Fig. 39 shows a sketch plan of the 100 feet level. The country rock is a decomposed amphibolite schist striking 340deg. and dipping to the east.

On the hanging wall of the eastern workings a banded quartzite strikes parallel to the schists and also dips east forming a barrier to the quartz reefs which, as soon as they meet the quartzites, are diverted and follow the footwall of the latter. The quartzites are here non-ferruginous but very evenly banded. Two parallel reefs have been driven on, on a bearing of 300deg. or roughly N.W. The main cross-cut has been run out for 170 feet beyond the west reef without showing any development of importance except a 6in. quartz reef dipping 30deg. to the S.W.

Fig. 39.



Sketch plan of 100ft. level, Associated Mount Jackson Gold Mines, Ltd., G.M.L. 451.

The main reefs are steeply inclined at 80deg. to the N.E. North of the main shaft minor faults are very common, giving displacements up to three feet. They are all right-handed faults.

A dismantled 10-head battery is on the mine, and no work has been done for years.

On G.M.L. 246 and 450, known as the Golden Lady Hay and the Alpha respectively, there is a large reef striking north and dipping to the west between 50deg. and 60deg. This is faulted in places with a total displacement up to 57 feet, but to the left hand, which could be accounted for by the opposite character of the dip to other reefs in the district. The reef abuts against banded quartzites dipping E., but in what relation is not shown in the workings.

A number of shafts have been put down on the Lady Hay line of reef, and the workings, though inaccessible, have not been carried to any depth. Judging by the Mines Department statistics the work on this company's properties has not proved satisfactory.

The following are returns supplied from Mines Department's statistics:—

Table showing the Yield.

Year.	Tonnage.	Gold in fine ozs.
1900	76.00	73.95
1902	725.50	150.76
	801·50	**224·71**

Victoria Reef Mine, G.M.L. 2564.—On this lease there is a dismantled 5-head battery. The workings are in a state of collapse and could not be inspected.

The mine is in a direct line of strike with the reefs of the Mt. Jackson Gold Mines, Ltd., and is probably a continuation of the same kind of reef. Not much ore has been crushed from this mine, as is shown by a yield of only 5.14ozs. from 27 tons of ore in 1912.

Mt. Jackson Wonder Mine, G.M.L. 2397.—This mine is situated about two miles south of Jackson townsite and was abandoned at the time of my visit. It was described as follows by Mr. H. P. Woodward after a tour of inspection of the district in [illegible]:—

> A formation 30 feet in width containing small veins of quartz has been developed by means of a 40ft. shaft, with a drive 20ft. north and 27ft. south, and crosscutting 35ft. east with a drive 10ft. north at the end of it. This formation has a general strike of north and south, with perhaps a slight dip to the east, but upon this point it is at present impossible to make a definite statement.
>
> A number of pits have been sunk upon rich quartz leaders, which are usually ferruginous although occasionally quite white. Upon one of these a small shaft has been sunk to a depth of 15 feet, from which some very rich stone was raised.
>
> The gold is mainly carried in the small irregular leaders, but the formation is said also to yield appreciable quantities upon assay, although it is impossible for me to make a definite statement on this point without systematic sampling.

The mine gave a return of 44.27ozs. from 120 tons of ore in 1912.

Athlone Mine, five miles north of Jackson. There are some workings which are now flooded and known as the Athlone.

These workings and those on the General Roberts were also visited by Mr. Woodward in 1911, when he reported as follows:—

> To the northward of the old mines a new discovery has been made at a distance of five miles, known as the Athlone, from the name given to the first lease pegged, upon which a reef striking N.N.E. and S.S.W. with an almost vertical dip has been sunk upon to a depth of 30 feet, but since a heavy body of salt water was encountered at a depth of 25 feet it was driven on at this depth.
>
> In this level, to the northward of the shaft, the reef forms into a solid body of quartz for a distance of 10 feet, when it pinches clean out. Its largest dimensions in this distance is 2ft. 6in.
>
> In the south level a broken mass of stone about two feet in width was met with for a distance of 20 feet, at which point it is cut clean off by a solid quartz reef which only carries values at its point of contact with the auriferous body.
>
> This reef did not outcrop and was not encountered until eight feet had been sunk; it was generally small and much broken in the shaft, but forms into a solid body at the shaft bottom. Judging from appearance it is of a pipe-like form with a pitch to the northward, the length of the shoot being 30 feet, and its average width about two feet. There is every possibility of this shoot lengthening with depth, whilst so far the size promises to increase.
>
> The stone is of a banded cherty character showing a considerable quantity of gold, whilst it yields an excellent prospect of fine gold when apparently barren stone is dollied. There is a small quartz vein which contains a considerable quantity of hornblende and prospects well exposed in a trench to the east of the shaft, but no traces of this were met with in the workings.
>
> About 30 feet west a parallel reef about nine inches in width with a westerly dip has been sunk upon to a depth of 30 feet by means of a shaft, in which the volume of water was considerably less than in the other.
>
> Still further is another reef upon which the original discovery was made. This outcrops for a length of 40 feet, and has been sunk upon to a depth of 25 feet.
>
> The stone is about three feet in the widest part, and is more ironstained and sugary in character than the eastern reefs, but is not so rich.
>
> The water is extremely salt, the yield from the first shaft being 6,000 gallons per day and the second 1,200 gallons.
>
> The General Roberts is north of the Athlone, and upon it a shaft has been sunk to a depth of 20 feet upon a small vein of stone which is exposed in a series of trenches for a distance of five chains. Upon the other leases of this group no work has been done.

The returns for the Athlone mine in the mining statistics are as follows:—

	Tonnage.	Gold therefrom, fine ozs.
1911—Athlone Reward Leases 2284, 2285	5.00	22.20
1912—Athlone Reward Leases 2284, 2285	100.00	82.61
	105·00	**104·81**

The average is 1oz. per ton.

There do not appear to be any lode formations associated with the ferruginous quartzites at Jackson, probably owing to the parallelism of their strike with the foliation of the schists.

MARDA.

This centre is situated 10 miles due east of Jackson townsite, and towards the centre of the greenstone belt. The geological features are essentially different to those at Jackson, the chief difference being in the E. and W. strike of the rocks and the absence of schistosity at Marda. The rocks are composed of a series of tilted and metamorphosed acid and basic lava flows. The ore deposits are confined to these, none being so far found in the sedimentary series that caps them at various places.

QUARTZ REEFS.

The quartz reefs are irregularly distributed in both the acid and basic rocks of the series and strike and dip in almost any direction. There are, however, three directions in which they occur most commonly, viz.:—

(1) North-west and south-east, dipping to the north-east.
(2) North-east and south-west, dipping to the north-west.
(3) North and south, dipping to the west.

These probably represent three directions of fissuring in a massive rock due to strain induced by great earth movements. It will be noticed that two of these directions correspond with those at Jackson. At Marda, however, the reefs are not so regularly distributed nor so persistent in outcrop.

This field is different from any other goldfield owing to the irregular trend of the reefs, an irregularity due to the rocks being massive and not fissured and sheared in the usual north-northwesterly direction. The reason for this is obviously because the series strike almost east and west, namely, at right angles to the great lateral pressures to which they have been subjected in common with all the rocks of the eastern goldfields.

The result is contorted quartzites and irregularly fissured rocks, with an absence of schistose structure and regular shear zones; hence the irregular form and distribution of the quartz reefs. The gold occurs in the reefs as short rich shoots, generally at the intersection of another reef, or alongside a brecciated pipe or zone in the ore channel. In most cases the reefs are short and lens shaped. and some difficulty is entailed in locating fresh chutes of gold, sometimes necessitating a great amount of dead work which eats up the profit earned from the last chute.

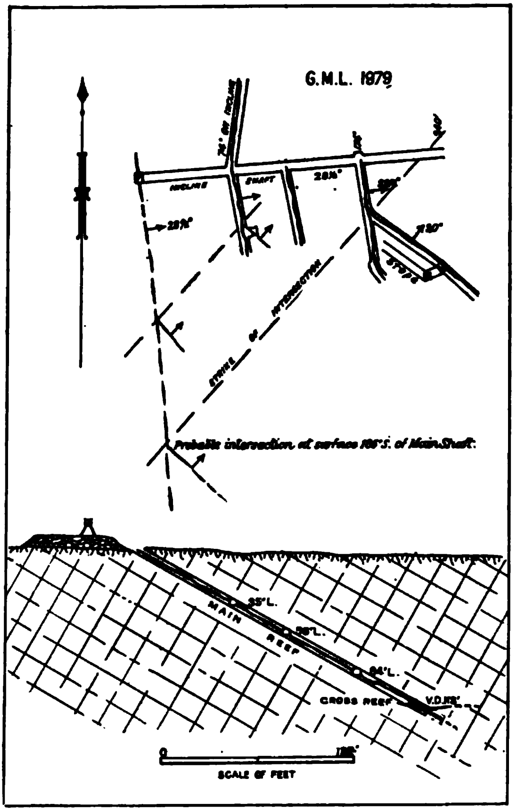
The principal mines are:—

Allen's Find.
The Great Unknown.
The Butcher Bird.
The Standard.

Allen's Find Mine, G.M.L. 1979.—Since writing the preliminary report which appeared in the Annual Report for 1914, it has been undoubtedly proved on further careful examination of specimens that Allen's Find occurs in a decomposed acid igneous rock, probably a quartz porphyry belonging to the volcanic series.

The country rock on this mine is very decomposed and in hand specimens is a soft greenish white rock composed of kaolin and quartz and traversed by veinlets of quartz. The main reef strikes a little west of north and dips to the east at 28°.

Fig. 40.



Sketch plan and cross section, Allen's Find, G.M.L. 1979.

An inclined shaft has been sunk on the reef to 240 or to a vertical depth of 113 feet. At a depth 74 feet on the incline (33 feet vertical), levels are driven north and south on the reef for 65 feet and 55 feet respectively. At 116 feet on the incline (56 feet vertical), a level has been driven south for 50 feet, and at 174 feet incline (82 feet vertical), a level south for 80 feet, with a drive off it at 35 feet from the shaft on a cross reef for 100 feet. The main reef varies in width from two to five feet and is a uniform body of stone. The cross reef that cuts it at the lowest level is also a well formed reef of from two to three feet in width, but has a shallow dip of only 20° to the north-east. There is another parallel cross reef cutting the main reef at the first level. The main reef has been stoped to the north of the shaft from the surface to the first level, and to the south of the shaft from the first level to the bottom level. The gold appears to occur at the intersections of the main reef and cross reefs. There should, therefore, be about 200 feet of backs along the intersection from the bottom level. The calculated intersection of the two reefs pitches to the north-east, and should cut the outcrop of the main reef on the surface at about 160 feet south of the mouth of the shaft. There is a dark seam of pug, a fraction of an inch thick, which can be seen following the footwall of the reef in the shaft. At the bottom of the shaft there is a big body of stone completely filling the face, and probably the continuation of the junction which occurs in the bottom level. At the junction of the main reef and the cross reef the quartz is brecciated and cemented by opaque to black quartz, caused by either a ferruginous or manganous staining.

This brecciation seems to be a characteristic of the intersection, but not sufficient stone was exposed to show which reef cut the other. The following is a plan and section of the mine workings:—

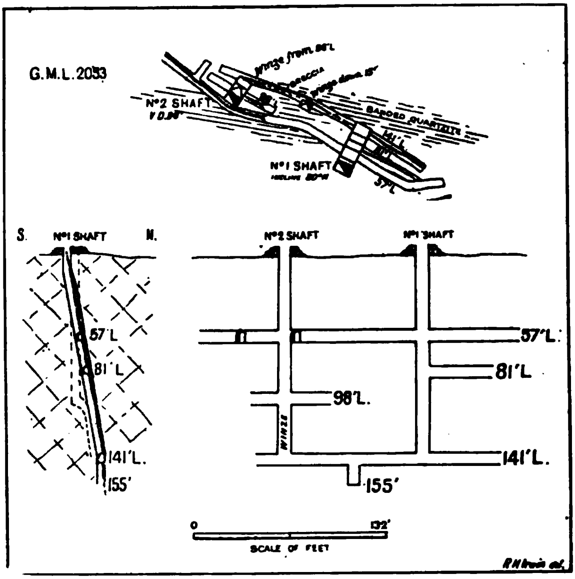
Statistics from the Mines Department's reports give the following gold yields:—

Year.	Tonnage.	Gold therefrom.
		Fine ozs.
1912	139·30	106·23
1913	199·25	213·76
1914	300·00	174·87
1915	553·50	223·81
1916	319·00	59·15
Total	1,511·05	777·82

The first two years give an average of 19 dwts. per ton. In 1914 the average has fallen considerably below that figure, but should be high enough to pay expenses. At the intersection of the two reefs there is a big body of stone. This mine shows great promise, with a chance of enrichment as the sulphide zone is approached. I should recommend sinking a vertical shaft to the east so as to cut the reef at about 200 to 250 feet vertical depth. This would test the reef at the least cost and ensure economical working.

THE GREAT UNKNOWN MINE, G.M.L. 2053.—This mine is situated 1½ miles north-west of the Marda Tank and one mile a little east of south of Allen's Find. Two shafts have been sunk on a reef striking 300°. No. 1 or east shaft is sunk on an inclination of 80° to the east. No. 2 or west shaft has been sunk through the reef to a depth of 98 feet, from which level a winze is sunk on the reef to 141 feet.

Fig. 41.



Sketch plan and longitudinal section of Great Unknown Gold Mine, G.M.L. 2053.

There are levels at 57 feet, 81 feet, and 141 feet, and the greatest length of reef driven on is 225 feet on the 57 feet level, and 170 feet on the 141 feet level. The greatest depth attained is 155 feet in a winze sunk on the eastern edge of a pipe of breccia. Fig. 41 is a Plan, Cross and Longitudinal section of this mine.

The country rock in the Great Unknown mine is a totally different rock to that on Allen's Find, though belonging to the same series. It is a carbonated ultra-basic igneous rock, and its chemical composition corresponds with a carbonated peridotite. The ore body is a quartz reef in a chloritic shear zone of about four feet wide in the carbonated country rock.

Unlike Allen's Reef it is practically vertical with an underlay of 80° to the east. The reef varies from six inches to three feet and averages about 18 inches. It takes an irregular course in the shear zone and is generally near the centre though in places follows either wall of the shear zone. In the country rock there is a band of quartzite, similar to the banded ferruginous quartzites in the neighbourhood and parallel to them. This quartzite strikes almost east and west, and is cut by the reef which strikes 300° at a very acute angle. The shear zone has sheared the quartzite into a breccia which has formed an obstruction in the ore channel, causing the reef to bifurcate and envelope the breccia connecting on the other side forming a solid reef again in the shear zone. The contact line of the reef and quartzite (jasper) is vertical, and therefore the horse of breccia forms a vertical pipe enclosed in the quartz reef. In the neighbourhood of either side of this breccia there is, according to the owners, an enrichment of gold.

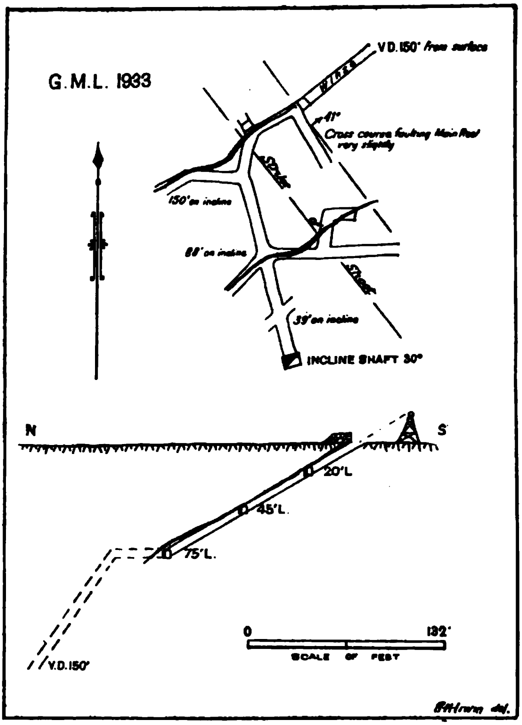
The ore shoots are also vertical and therefore parallel to the pipe of breccia. There are three ore shoots according to information obtained from the prospectors of the mine. One on either side of the pipe of breccia, and one at the eastern end of the workings which as far as could be seen was unconnected with any structural feature. The quartz is heavily mineralised and frequently shows coarse gold. The returns from this mine give the stone a high average value, though probably the richest portions only of the reef have so far been treated. There is a large quantity of stone at grass which is expected to crush an ounce to the ton. The statistics are as follows:—

Year.	Tonnage.	Gold therefrom.
		Fine ozs.
1911	37·88	267·09 Dollied 37·22
1912	411·05	1,374·63
1913	306·00	1.094·05
1914	123·00	393·36
1915	180·50	199·81
1916	167·00	140·98
Total	**1,225·48**	**3,507·14**

Average 2·86ozs. per ton.

Butcher Bird Mine, G.M.L. 1933 (Atkinson's), is situated 2¼ miles slightly east of north of the Marda Tank. The reef has a general strike of 65° and dips 30° to the north-north-west. An incline shaft has been sunk on the reef for 150 feet, passing into the footwall near the bottom which has a vertical depth of 75 feet. At 88 feet on the incline there is another level. Down to 40 feet there is an irregular network of workings. About 60 feet east of the main shaft on the 75 feet level there is a winze sunk on a fault plane dipping 40° east to a depth of 90 feet. The water level is 63 feet below the 75 feet level, making a total vertical depth of 138 feet below the surface. At the time of my visit there was not sufficient water to work the mill, but an adequate supply should be assured by further sinking. The mill has since been supplied with water by a pipe-line from the Marda dam.

Fig. 42.



Sketch plan and cross section, Butcher Bird No. 1 Gold Mine, G.M.L. 1933.

In the west end of the drive, in the 75 feet level, the reef is still big and strong, but is said to be poor in value. In the east end the fault plane on which the winze is sunk cuts the reef off, though not altogether, as the fissure line corresponding with the reef can be seen east of the fault line (Fig. 42).

The country rock on this mine is a decomposed dolerite and is intermediate in composition between the more acid rock on Allen's and the more basic on the Great Unknown. The reef also from both the above mines, being less regular in trend, aving a wavy course. The wave or roll in the reef determines sition of the ore shoot which seems to follow the pitch of the n fold of the wave. The reef ranges in width from 1 foot to t. Just overhead on the 75 feet level, near the winze, and on otwall of the reef, there is a patch of arsenates of iron, ing scorodite and pharmacosiderite. The former is a pale granular mineral and the latter occurs as bright emerald cubic crystals. Associated with these is arsenical pyrites and es, and the green minerals have no doubt been formed by the ation of the arsenical pyrites. Gold is freely distributed in the mineral and the quartz.

A specimen from this occurrence is fully described by Mr. on below (pp. 181-183).

Gold mining statistics show the following yield from this e:—

Year.	Tonnage.	Gold therefrom.
		Fine ozs.
.. ..	288·00	266·70
.. ..	215·00	160·01
.. ..	60·00	50·07
	563·00	**476·78**

Average—17dwts. per ton.

The following notes on the minerals in the gold ore from the er Bird Mine have been supplied by Mr. E. S. Simpson, the ralogist and Chemist:—

MINERALS IN GOLD ORE FROM THE BUTCHER BIRD G.M., MARDA.

By E. S. Simpson, Mineralogist and Chemist.

An examination of the specimens of gold ore collected by Mr. an at the Butcher Bird G.M., Marda, reveals the presence of nerals, viz., in relative order of frequency:—

Quartz, Scorodite, Pharmacosiderite, Arsenopyrite, Pyrite, and Gold.

Quartz.—Milky white quartz forms the main gangue.

Scorodite.—Hydrated arsenate of iron, $Fe_2O_3.As_2O_5+4H_2O$. quartz, this is the commonest mineral present. It forms large mall irregularly shaped masses, not visibly crystallised, but intly granular in structure. It is pale grey-green in colour.

Like pharmacosiderite it is composed of ferric oxide, arsenic oxide, and water, but its individuality is established by its much higher specific gravity, in this case 3.26, and by its proving to be anisotropic between crossed nicols.

"Scorodite has previously been observed in this State at Federal Downs (Kimberley) in tin ore, with cassiterite and quartz; and at Warriedar (Murchison) in gold ore at the Porcupine G.M., with jasper, arsenopyrite, and a copper arsenate (erinite?).

"Scorodite is somewhat widely distributed in Australia, having been recorded from numerous mines in Queensland, Victoria, Northern Territory, and Tasmania, and from two localities in New South Wales.

"*Pharmacosiderite* (hydrated basic arsenate of iron, with potash (?), formula uncertain, perhaps "$FeAsO_4.Fe[O(H,K)]_3.5H_2O$").* This is the most striking constituent of the ore, occurring in well formed crystals of a rich green colour, ranging in size from 1mm. to 4mm. The crystals are developed either as a partial filling of cavities in quartz, which were once filled with arsenopyrite, or embedded singly or in groups in the centre of masses of scorodite. The common form is the simple cube of the isometric system, but occasional crystals are seen in which half the corners of the cube are truncated by the faces of the tetrahedron, or by oscillatory combination of the cube and tetrahedron. Interpenetration twins resembling those of fluorite are fairly common.

"The specific gravity of small crystals was proved to be 2.85. This figure, as also that for the scorodite, was obtained by interpolation in the following series, using methylene iodide as the suspending fluid:—

Olivine, Navajo Reserve, U.S.A.	3.32
Spodumene, Ravensthorpe, W.A.	3.14
Rubellite, Elba, It.	3.01
Aragonite, Melbourne, Vic.	2.93
Calcite, Coolgardie, W.A.	2.71

"Pharmacosiderite is a somewhat rare mineral, and there is no record of any other locality for it in this State. It is, however, reported to occur in several localities in Victoria, as well as two in New South Wales, and two in Tasmania.

"*Arsenopyrite.*—This is abundant in one of the two specimens collected by Mr. Honman, and is present in small amounts in the second. It is plainly the mineral from which both the arsenates have been derived.

"*Pyrite.*—A few small crystals (cubes and pyritohedrons) of this mineral occur in the solid quartz, where weathering agencies have not been able to reach them.

"*Gold.*—Free gold in fine to moderately coarse particles is freely distributed through the ore. It is seen attached to the sides ities from which arsenopyrite has weathered out, as well as em- d in unweathered arsenopyrite and in quartz and covering re faces.

---

* E. G. J. Hartley, Min. Mag. XII., 157.

“*Occurrence.*—Mr. Honman informs me that the specimens taken from a small patch of similar material occurring on twall side of the reef at a depth of 75 feet.

“*Paragenesis.*—A study of the ore and its occurrence points e primary minerals being quartz, with a minor amount of opyrite in irregular masses and bunches of various sizes em- ld in it. The greater part of the gold, too, I am inclined to der as primary, having originally been embedded either in z or in arsenopyrite. In the latter case it now mostly appears r embedded in scorodite or attached to the walls of empty or ially filled cavities left by the solution of arsenopyrite.

“The co-existence of two different arsenates of ferric iron is in- ting, and a study of it is likely to shed light upon the general ion of the weathering of sulphide ores.

“The mineral pharmacosiderite which appears so freely in the imens is of unusual interest in view of the complete uncertainty arding its exact chemical composition. Only two analyses have been made of it, viz., one in Sweden in 1824, one in England in . There are serious and inexplicable differences between these, two formulæ deduced from them being

$4Fe_2O_3.3As_2O_5.15H_2O$ (Berzelius), and
$2FeAsO_4.FeO_3(H.K)_3.5H_2O$ (Hartley).

“In view of these facts I would urge that every effort be made cure for detailed examinations some further specimens from ia, particularly of material containing well defined crystals.”

STANDARD MINE, G.M.L. 2548.—Garrett and party and subse- ly Saunders & Don:

This mine is situated one mile a little south of east of the rda tank.

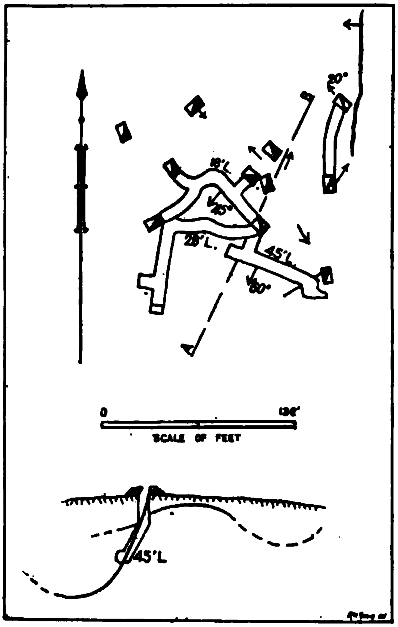
The workings of this mine are such a ramification of shafts, s, cross-cuts, and stopes that an intelligible pen description is le extremely difficult. This is owing to the irregular course of reefs, there being apparently a number of wavy reefs that cross d twist in a most remarkable manner. Eleven prospecting shafts e been put down within an area of one-third of an acre.

The main shaft is sunk vertically for 18 feet, and then on the ne at 60° to 45 feet on a reef dipping 60° south to the east of haft and 45° south-west to the west of the shaft. North of the in shaft the cap of dome-shaped reef comes within a few feet of urface. This reef dips away in all directions and cuts the reef the main shaft at 18 feet.

There is a north and south reef dipping 20° west, which is poor value, and other narrow reefs are cut in the shafts dipping in all irections. The deepest workings are not more than 60 feet.

The country rock is decomposed dolerite and very similar to t Butcher Bird rock. The reefs vary from a few inches up to two three feet wide, and often tail out to thin veins; judging by the pos tions of the stopes the ore appears to come from the dome portic

Fig. 43.



Sketch plan and cross section, Standard Gold Mine.

of the reef, at curved portions and close to intersections of two reefs. Fig. 43 shows sketch plan and section of the mine. Some rich crushings have come out of this mine, as the following statistics testify:—

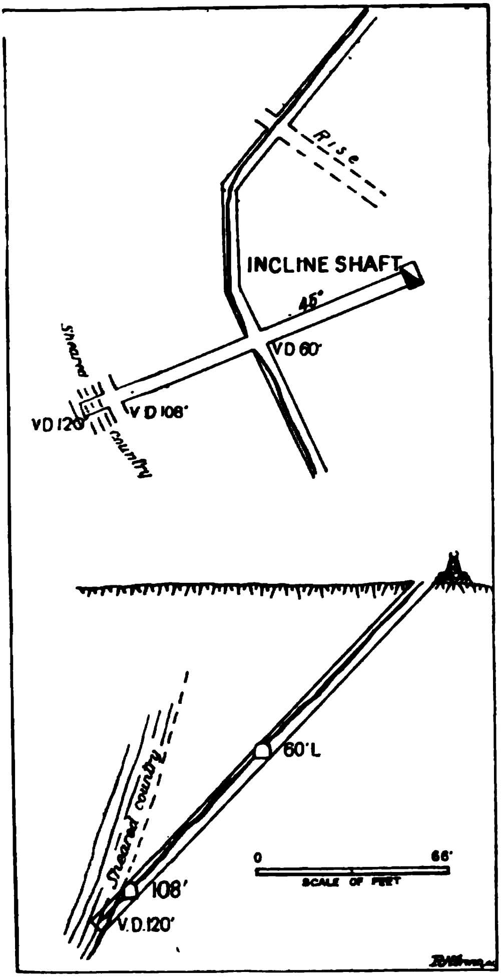
Year.	Tonnage.	Gold therefrom.
		fine ozs.
1912	67·00	355·13
1913	182·00	522·56
	249·00	877·69

Average—3·5 ozs. per ton.

THE MINER'S DREAM MINE, G.M.L. 2190.

Another mine which has been developed systematically but so far with poor results is the Miner's Dream. This is an anticlinal

Fig. 44.



Sketch plan and cross section,
Miner's Dream Gold Mine.

reef pitching to the west at 45°. A main shaft has been sunk to 170 feet on the incline of 45° or V.D. 120 feet. There is a level at 80 feet on the incline which has been driven on for 100 feet north and 50 feet south. The ore shoot pitches to the north, on the northern leg of the antidine, but has so far not proved payable.

The country rock is decomposed, kaolinised and white. Near the bottom of the shaft the country is sheared. The reef is a solid body of quartz varying from 12 inches to two or three feet in width. Crushings taken out gave the following results:—

Year.	Tonnage.	Yield, fine ozs.
1912	45.00	16.42
1914	31.00	19.11
1915	349.00	93.81
Total	425.00	129.34

Average, 6dwts. to the ton.

The continuation of this line of reef can be followed on the surface for some distance to the northwards. The manager, Mr. Gilbert, intended sinking on the shoot of gold, and it is to be hoped he will have better luck, as it is not unlikely, owing to the decomposed nature of the ground at the bottom of the shaft, that the values will improve at depth. Fig. 44 is a sketch plan and section of the mine.

There are many other shows which are in the early stages of prospecting, some which have been abandoned, but from which, according to report, some rich patches of ore have been obtained. Most of the reefs are highly mineralised and of very promising appearance, but many are small and short.

THE UNKNOWN SOUTH, G.M.L. 2594, is a lease which, from a geological point of view, has possibilities. At the south end of the lease a prospecting shaft is sunk on a reef which is exactly similar to the Great Unknown reef, carrying the same mineral and showing free gold. It is on the continuation of the line of strike of the Unknown reef, and though in unsettled country, appears to occur in a shear zone and possibly the same as the Great Unknown. The reef is certainly in the same ore channel with the same dip and strike, and I am informed that good prospects can be obtained from floaters between this shaft and the Great Unknown mine.

The following sundry returns have been recorded from Marda:—

Year.	Name of Lease.	Tonnage.	Gold therefrom
			fine ozs.
1911	Effie's Reward, G.M.L. 2271 ..	·25	3·70
1911	Flemington, G.M.L. 2362	..	* 4·36
1911	Marda East, G.M.L. 2387	7·50	12·01
1911	Queen of the Hills, G.M.L. 2300 ..	8·00	20·85
1911	Three Kings, G.M.L. 2157	10·00	12·31
1912	Best Known, G.M.L. 2547	20·80	33·35
1912	General Jackson, G.M.L. 2505 ..	36·00	26·27
1912	Great Unknown North, G.M.L. 2444	11·00	23·07
1913	„ „ „ „	14·50	12·46
1912	Inglewood, G.M.L. 2156	13·50	8·96
1912	Known Best, G.M.L. 2602	12·00	13·93
1912	Persian, G.M.L. 2527	16·00	31·96
1912	Titanic, G.M.L. 2614..	13·50	18·69
1913	„ „ „	12·50	6·23
1913	Well Known, G.M.L. 2569	6·00	6·96
1913	Sundry Claims	208·40	116·70
1913	Just in Time, G.M.L. 2597	10·00	12·20
1913	Lone Chance, G.M.L. 2636	10·00	6·77
1913	Newmarket, G.M.L. 2713	9·00	30·48
1913	„ „ „	..	*42·68
1913	Titanic	12·50	6·23
1913	Sundry Claims	752·10	481·11
1913	„ „	..	*8·92
1914	Sundry Claims	98·00	66·07
		1,281·55	1,006·27
1916	Total, Sundry Claims	359·75	201·85
		1,641·30	1,208·12

* Dollied.

FERRUGINOUS QUARTZITE (JASPER) LODES.

This class of lode has so far not proved profitable on this field, is not likely to be until the field has gone ahead, owing to their ing, if payable at all, low grade propositions and therefore neces- ting greater facilities for mining than the field at present pro- des. They consist of lodes in ferruginous quartzite which have n sheared or crushed sufficiently to have formed in them many ll cracks which have become filled with quartz. So that you e a quartzite riddled with veinlets of quartz. The gold, accord- to all accounts, occurs exclusively in the quartz, forming a low rade formation with an irregular distribution of gold owing to the oradic arrangement of the quartz veins. Typical examples of ese lode formations are the Mount Bacon and Burgoose leases, and the Canopus, G.M.L. 2511. It is only where the ferruginous quart ites are distorted or sheared that they are auriferous, as there a many miles of outcrop of ferruginous quartzite which are perfect barren of gold. There is, however, every likelihood that payab reefs may be found outside the lodes which may be enriched whe they meet or cross the lodes.

YARBU.

Yarbu is situated seven miles west-north-west of Pigeon rocl and is close to the granite contact. The country rock consists c decomposed ancient sediments, being composed of alternating banc of coarse and fine grained schists, which are probably of sedimer tary origin. The schists strike north-north-west and dip 70deg. t the east. A number of leases were taken up about the time o the Bullfinch boom. The principal mine was the Bronzewing G.M.I 2336. Three prospecting shafts have been sunk on this lease to cu a gently inclined narrow reef dipping 15deg. to the south-east. Th reef varies from 6in. to 9in. in width and is composed of a clea glassy looking quartz. Mining statistics give the good yield o 60.03 ozs. from 44.5 tons of ore from this show in 1912.

Another show, G.M.L. 2310, gives a yield of 16.42ozs. fron 10.00 tons of ore. Other reefs at this centre are generally narrow and composed of glassy quartz. One has a dip as shallow as 10deg west and others are vertical or steeply inclined. The reefs so fai worked appear to be too small to be worked at a profit, and, generally, developments as far as they go are not promising.

There is some country worth prospecting between Yarbu anc Jackson near the granite contact. Quartz outcrops are numerous and geological conditions favourable.

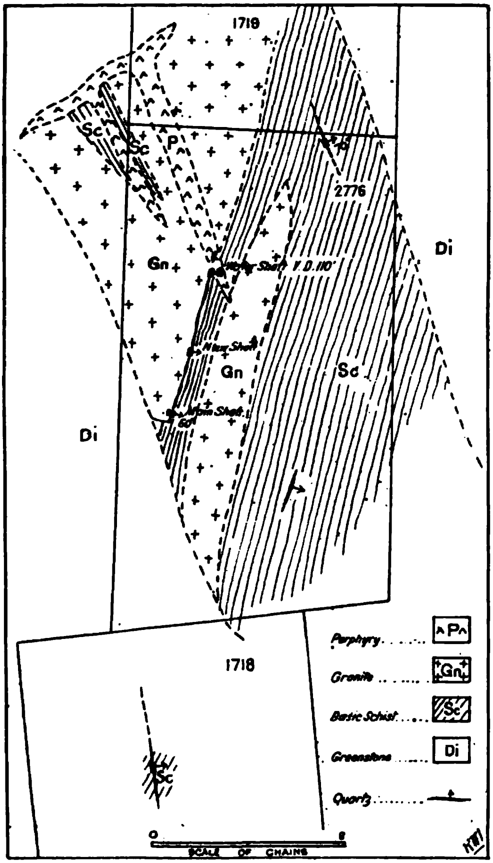
KOOLYANOBBING.

This centre is situated 35 miles north-east of Southern Cross, and occurs in a lens-shaped belt of greenstone 35 miles long, five miles wide, and striking to the north-west. Gold was first discovered here in 1904, and a reward claim was granted to Mr. Chadwick of Southern Cross.

The principal workings are situated on the Rainbow leases, G.M.Ls. 1718, 1719, and 2776, which are situated about 2¾ miles north-east of Koolyanobbing Trigonometrical Station and half a mile south-east of the Government tank.

CLARK'S SYNDICATE MINE, G.M.L. 2776, was being worked at the time of my visit. The main reef is along the contact of granite and a basic schist, strikes north-north-east and 60deg. to the east. It varies in width from six inches to three feet. The reef can be followed on the surface for 500 feet. Most of the work has been done on the south end of the reef, which has been stoped down to 48 feet for a length of, roughly, 50 feet. An incline shaft is sunk on the reef and at 48 feet the reef is driven on 45 feet to the north and 28 feet to the south. At the south end the reef is faulted to the right which is the same direction of throw as at Jackson. The displacement is eight feet at the bottom of the shaft, the granite intrudes the basic schist hanging wall, and north of this intrusion the ore shoot occurs. Gold shows in the reef three chains north of the main shaft and the present owners are sinking on the reef at this point. At the northern visible extremity of the reef a prospecting pit shows that the reef has straightened up, being almost vertical with a dip to the west. East of the pit a shaft has been sunk to a depth

Fig. 45.



Geological sketch plan of Rainbow leases.

of 110 feet showing basic schist at the bottom overlying granite, dipping 30 deg. south-east. At 20 feet from the bottom there is a three feet band of basic schist dipping 30deg. south in granite. This shaft passes through a felsitic porphyry but where it cuts the porphyry is hidden by the timbering of the shaft. From the north-west corner of the lease an arm of felsitic porphyry striking south-east cuts the northern end of the main reef.

About six chains east of the main shaft there is a parallel reef dipping east. Near the northern boundary of the lease and a few chains west of the north-east peg there is a reef striking north-north-west and dipping east.

Fig. 45 is a sketch plan of the geology in the vicinity of the workings of the Rainbow leases.

Adjoining the south end of G.M.L. 1718, Prospecting Area 400 has been pegged, and a shaft sunk to about 50 feet on a vertical reef up to 18 in width and striking 18deg. east of north. This reef occurs in the sheared eastern margin of a boss of felsitic porphyry.

About 1½ miles east of the Rainbow lease is an abandoned five-head battery, and 35 chains east again a Government well from which water was obtained for crushing purposes, the water level of which was about 60 feet from the surface, and the total depth of the well about 160 feet.

CHADWICK'S REWARD MINE, G.M.L. 641 (abandoned) is 2¾ miles south-east of Koolyanobbing Trigonometrical Station, and one mile from the main granite contact. Here they have worked a narrow quartz reef, in decomposed fine grained greenstone, but values are reported to be on the low side.

South of Chadwick Reward there are some old workings alongside the granite contact, along which there is a large buck quartz reef (see Fig. 46) which outcrops for miles and can be seen outcropping on the south-east side of Lake Seabrook. The old workings above referred to are on a narrow portion of this buck reef. One wall of the reef carries copper carbonates, but not rich enough to form copper ore.

At these workings some interesting contact rocks occur. The granite does not abut against the greenstone but has a contact margin of gneiss. This gneiss contains large rounded crystals of felspar enveloped by gneiss giving a typical eye structure. The foliation of the gneiss bends round the felspar crystals.

The gneiss becomes more basic near the greenstone, changing into an evenly banded hornblende gneiss. This is followed by amphibolite schist, impregnated with crystals of magnetite and crushed talcose schists.

About two miles north of Chadwick's Reward, on the track to the Rainbow leases, there occurs in greenstone schist a large body of quartz 20 feet wide in places and 500 feet long, and carrying galena and zinc blende. This should be worth sampling.

I have been informed that there is auriferous country about 10 miles north-east of Koolyanobbing, but I did not have an opportunity of visiting it. It is probably part of the belt that crosses

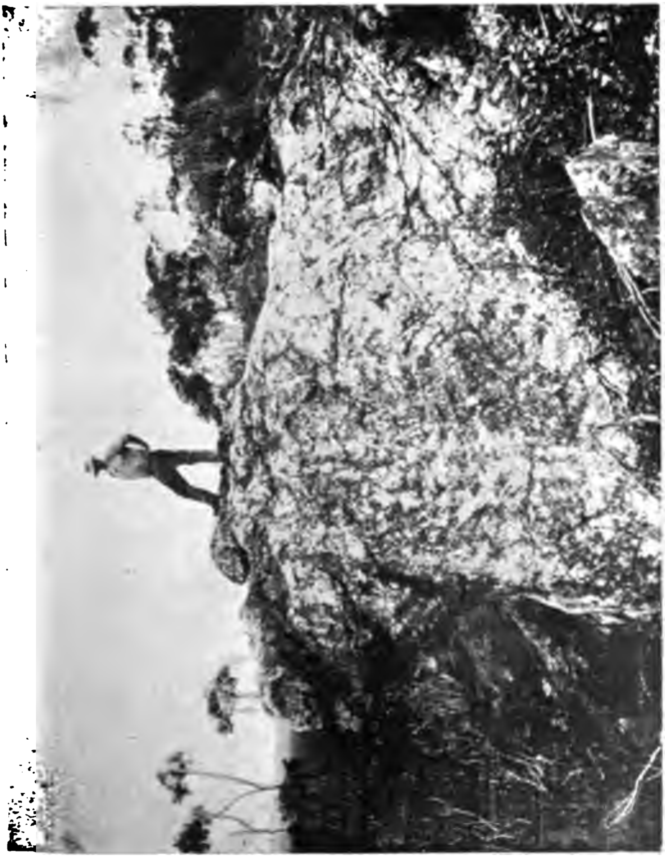


Fig. 40.

Photo: C. S. Honman.

Neg. 1370.

Quartz blow three miles south-east of Koolyanobbing.

the Glen Rynn track 7½ miles north-north-east of Koolyanobbing Trig. Between this development of greenstone and the Koolyanobbing belt there appears to be an extensive development of gneiss.

The following are the returns for Koolyanobbing:—

Year.	Name of Lease.	Tonnage.	Yield.
			Fine ozs.
1905	Chadwick's Reward	6·00	2·65
1908	St. Clair, No. 2 South G.M.L., 783	23·00	16·07
1910	Jupiter, 909	12·00	9·15
	Saturn	28·00	2·07
	St. Clair, No. 2 South	239·00	86·80
1911	Sundry Claims	55·00	10·40
1912	Sundry Claims	..	·84
	Total	363·00	127·98

BUNGALBIN RANGES.

Bungalbin Trigonometrical Station is situated 31 miles north-north-east of Koolyanobbing and is the most prominent point in a rugged range of ferruginous quartzite (Jaspers) rising from the continuation of the Jackson greenstone belt. The greenstone is about 12 miles wide here, and practically no prospecting has been done in spite of the favourable geological conditions that prevail.

Both contacts with the granite to the north and south should be well worth prospecting, especially in the vicinity of the Bungalbin ranges where the rocks appear to have been subjected to great disturbance, and therefore likely to contain a zone along which fractures and fissures have been provided for the deposition of quartz reefs.

IRON.

Of deposits other than gold there are none that have been worked up to the present in this district. Yet there are big bodies of iron ore which may some day be of great economic importance to the country.

Three classes of iron ore exist in the district:—

(1.) Segregations of haematite and magnetite in the folds and fractures of contorted ferruginous quartzites (Jasper). High grade ore.

(2.) Gossans of Goethite forming a capping possibly to sulphide lodes.

(3.) Haematite quartzites. Low grade ore.

The first class of ore is probably very widely represented, and should be found by an exploration of the contorted portions of the jasper ridges. An example occurs on the western slope of Koolyanobbing Trigonometrical Station (*vide* Appendix II.). A sample [$\frac{1}{51}$] of this ore proved to be the purest yet found in the State, nd is described by Mr. Simpson as Micaceous Haematite. The fol- wing is its composition:—

Fe_2O_3	98·75 %
SiO_2	1·04
P	·016
S	Trace
Ignition loss	·39

Analyst—D. G. Murray.

The second class of ore (Goethite) is associated with lines of ajor faulting or shearing in the haematite quartzites. It occurs

Neg. 1354.

Photo: C. S. Honman.

View from north side Koolyanobbing Trig., looking east.

r a huge mass in a big gap in the Mt. Jackson jasper ridge, ex- nding between Mt. Jackson Trig. and Boondine Trig. for nearly a mile in length. Great buttresses of Goethite occur along the ridge. (See Fig. 47.) A sample of this class of ore is thus reported on by Mr. Simpson:—

[1/47.] **Brown iron ore, near Mt. Jackson.**

The brown iron ore collected half-mile south-west of Mt. Jackson appears to the unaided eye to consist of two minerals, viz., a compact structureless mineral of a dark brown colour forming the main mass of the specimen, and a similarly coloured but distinctly fibrous mineral forming crusts on the former. The structure of the fibrous mineral is that of typical Goethite $Fe_2O_3 . H_2O$, and its identity with this mineral is confirmed by a partial analysis.

Picked fragments of the massive mineral had the following composition:—

Fe_2O_3	90.26	(Metallic Iron 63.18.)
H_2O	9.91	
SiO_2	traces	
	100.17	

Typical Goethite contains:—

Fe_2O_3	89.86
H_2O	10.14.
	100.00

The massive mineral is therefore also Goethite.

Massive Goethite forms a large proportion of the outcrop of the immense iron lode of Mt. Caudan, South Yilgarn, where it is derived from the oxidation of a lode which in depth consists largely of Pyrrhotite and magnetite I am of opinion that the present samples are from the outcrop of a similar sulphide lode, since iron lodes of the haematite-jasper type or magnetite-ilmenite type do not in this part of the world appear to give rise to masses of iron hydrates at the surface.

There is also a development of Goethite ore near Bungalbin Trig. At this place it is clearly seen to be a gossan forming a hard capping which has become undermined by caverns.

Of the third class of ore there must be immense quantities of low-grade material, since the haematite quartzites can be traced for a distance of 70 miles. There are, however, great variations in composition—from almost wholly silicious to wholly ferruginous quartzites.

The depth to which these iron ores extend has never been tested, but it is almost certain that no great depth will be attained except perhaps in the case of the first class deposit above mentioned.

COPPER.

No copper ores have been proved in the district, though there are indications such as the presence of carbonates associated with the contact reef, on the western contact of the Koolyanobbing greenstone and in the same line of strike as the western contact of the Jackson belt. At Koolyanobbing the indications are not very promising, but 11 miles south-south-east of Jackson, near the granite contact, there is a quartz reef in the greenstone that runs parallel with the contact at a few chains from it. This reef crosses the road about one mile north of the soak, and a reef at the same distance from the contact is exposed in a prospecting shaft one mile south and half a mile east of the soak. The latter outcrop shows an abundance of carbonate on one wall of the reef. But no more than that is to be seen in the prospecting pit is exposed, so that it is impossible to say whether it is of economic value or not, yet there are sufficient indications to justify a search being made along the line indicated, viz., the western contacts of the Jackson and Koolyanobbing greenstone belts. In connection with the copper-bearing reef near the 11-mile soak, an extraordinary feature which was pointed out to me by a local prospector was the total absence of vegetation on longitudinal belts of country parallel to the strike of the contact of the greenstone and granite, and starting from the prospecting pit exposing the carbonates of copper. Since these rare patches occur on the slopes of a rise, they could not be caused by swampy conditions, but must owe their origin to the composition of the soil or underlying rock having a deleterious effect on vegetation. The composition of the underlying rock, which is amphibolised dolerite or gabbro, os as follows:—

G.S.M $\frac{1}{14}$. G.S.L. 7459D.

SiO_2	49·17
Al_2O_3	15·39
Fe_2O_3	1·52
FeO	8·73
MnO	·21
MgO	8·29
CaO	11·11
Na_2O	2·22
K_2O	·06
H_2O —	·10
H_2O +	2·20
TiO_2	·59
CO_2	·06
P_2O_5	·10
FeS_2	trace
	99·75

Sp. Gr. 2·84.

Analyst .. .. .. H. Bowley.

VII.—ORE GENESIS.

A complete discussion on the origin of the ore deposits of this region would be impossible at the present stage of its development, certain facts in their relation to ore genesis can be pointed out, and any tentative conclusions drawn therefrom may be of some assistance in suggesting criteria for the location of fresh shoots in the already proved line of reef, and for the prospecting for new fields in the large belts of promising country at Jackson, Bungalbin, and Koolyanobbing.

The reefs of the region occupy zones of fracturing in the greenstone series. In a greenstone belt like the Jackson belt great earth movements have resulted in the weakest portions, or those portions of the belts subjected to the greatest force being fractured, resulting in zones of country riddled with fissures. These fissures will vary in arrangement according as the forces are compression, tension, torsion, or a combination of the three, hence the great variety of arrangement of reefs in different districts. In some fields the reefs are all parallel and dipping in the same direction, this is probably an effect produced by either shearing or tensile forces. In others approximately parallel, but dipping in opposite directions and due to compression. Again we find a most irregular arrangement forming a network of reefs with variable dips, probably due to twisting or torsion. As these forces are combined or superimposed the more complicated is the system of fissures. Now it is only natural that deep-seated solutions and vapours under pressure must take these zones of fractures as a means of escape, and on circulation in the fissures relief of pressure results, and deposition of reefs and minerals in the fissures. Where do these solutions obtain their mineral composition? It has been proved that the basic igneous rocks contain small percentages of base and precious metals, and it is significant that in all the large tracts of acid rocks no gold has been discovered unassociated with basic igneous rocks. If the deposits are not actually in the greenstones when occurring in granite the greenstones are never far distant. It is conceivable, therefore, that the solutions have obtained their metallic contents from the rocks in which they circulate. At Marda the reefs are most irregularly distributed in a block of greenstone country in which later intrusives are scarce, if not almost absent. The reefs occur alike in the acid rocks as well as the basic. In fact, the three principal mines are in three rocks of totally different composition though of contemporaneous origin. Thus:—

Allen's Find—Acid country rock.

Butcher Bird Standard—Basic country rock.

Great Unknown—Ultra basic country rock.

And in these mines the richest reefs are in the basic rocks, in which the quartz shows free gold. In the acid rock gold is not nearly so easily seen in the quartz, nor are the reefs so rich. This may of course be a coincidence, yet it is significant.

It is probable, therefore, that by a process of saturation of the rocks by deep-seated waters, weak metallic solutions have been formed, which. upon the rupture of the containing rock and the formation of open fissures, have ascended these fissures and deposited their mineral and metallic contents as a consequence of the attendant relief of pressure.

As regards the distribution of the gold in the reefs, it is a fact in the Marda field that the ore shoots are always associated with some structural feature, which would have either restricted, enhanced, or diverted the flow of a solution circulating in the fissure now occupied by the reef. In the three principal mines we have an illustration of three such different controlling factors.

(1) Obstruction in the Great Unknown Mine, in the form of a pipe of breccia crossing the ore channel. Result, an ore shoot on either side of the obstruction.

(2) Increase of flow and a meeting of solutions probably different in composition, temperature, and pressure at the junction of two reefs, as in Allen's Find. In this case the space occupied by the reef is greatly increased at the intersection, where two things might have happened: one, a slackening of the rate of flow and an attendant deposition of minerals; two, a reaction between two different solutions meeting. Result: ore shoots in the neighbourhood of the contact of two reefs.

(3) Diversion of flow as in the Butcher Bird Mine by a curvature in the course of the fissure. The shoot of gold in the Butcher Bird Mine, judging by the position of the stopes, corresponds almost exactly with the eastern arm of a pitching syncline in the reef.

The ore shoots in the Standard Mine were probably controlled by a combination of conditions (2) and (3), because the reefs on that mine are curved and also intersect one another.

The moral, therefore, is that prospectors cannot pay too much attention to the structural features on their mines with a view to interpreting their effect on the ore shoots. The reason is obvious in a search for new shoots of ore, as the following of a favourable structural feature will direct the dead work into those portions of the reef most likely to be productive and may sufficiently reduce the exploratory work to change a duffer into a payable concern.

As regards the mineralisation of the reefs, it is generally found that pyrites is most plentiful in the walls and near the walls of the reefs. For instance, in the Great Unknown Mine the chlorite carbonated shear zone contains 10 per cent. of pyrites and traces of gold and silver. In the quartz the most common minerals are galena, zinc blende, and arsenical and cupriferous pyrites.

The gold in many cases occurs intimately associated with any of the above minerals. The minerals are arranged in crudely arranged crusts, which usually succeed one another in the following order:—

(1) Pyrites in walls of reef.
(2) Pyrites in margin of reef.
(3) Calcite.
(4) Galena, Zinc Blende and Arsenopyrite near centre of reef.

This is a typical case of crustification, which is generally admitted to be a characteristic structure of a fissure filled by deposition from circulating solutions.

Secondary enrichment, though not actually observed in this field, is likely to occur in any of the mines, and if so, in the zone of change from oxidised to unoxidised country.

In the Great Unknown Mine the zone of possible enrichment is close to the surface, at about 75 feet, and the workings already extend well into unoxidised country.

The Butcher Bird Mine is still in oxidised country, but not far off the sulphide zone, and values should improve in depth until unoxidised country is struck.

Both Allen's Find and the Standard are still in decidedly oxidised country. It is therefore clear that all these mines have not yet nearly reached the limit of their productive zone in depth, but probably the value of the ore on the Great Unknown will decrease as the sulphide zone is penetrated further.

It should, therefore, be born in mind that if the high values so far obtained are due, to some extent, to secondary enrichment, which is more than likely, the value of the stone will not be so high below the zone of enrichment, though there is every indication that the reefs will be payable for some considerable depth. Past experience in this State has proved that the zone of enrichment may extend for 100 feet above and below the cap of the sulphide zone.

The Marda field, however, has not yet reached that stage at which the value of the ore at depth need cause any anxiety to the mine owners.

VIII.—CONCLUSIONS.

(1) Two series of rocks are represented and separated by an unconformity. The younger series has so far proved unproductive both here and in the Kalgoorlie district.

(2) Marda as a prospective mining field offers great inducements to small parties of prospectors, provided continuous crushing facilities are made available.

Some of the mines show great promise, and deserve the attention of capitalists and large companies. Of these, the Great Unknown and Allen's Find are most promising, especially the former, on account of the possibility of the reef extending through the South Unknown Lease.

(3) The old Jackson centre, though now deserted, is worthy of the attention of capitalists on account of the persistent nature of the reefs and their regular trend.

(4) Koolyanobbing is well worth further prospecting. Its extension northwards appears to have been practically untouched by prospecting parties.

(5) East of Marda there is a large tract of country which deserves more attention from the prospector. From the Marda tank to Bungalbin Range there is a continuous belt of greenstone country 25 miles long and from 10 to 15 miles wide. The intervening country and that around Bungalbin appears to be practically untouched, and new finds will probably be made here as the result of further and more systematic prospecting.

(6) Yarbu is a centre that is not particularly attractive from a mining point of view, though the country along the granite contact between here and Jackson should be worth prospecting.

Table showing the Yield of the Mount Jackson and Koolyanobbing Centres of the Yilgarn Goldfield, up to 30th June, 1915.

Mining Centre.	No. of Lease.	Name of Lease.	Dollied and Specimens.	Ore treated.	Fine Gold therefrom.
			fine ozs.	tons.	fine ozs.
Mt. Jackson.. ..	1979	Allen's Find	..	708·55	528·94
Do.	1933	Butcher Bird, No. 1	..	911·00	719·98
Do.	2053	Great Unknown	37·22	877·93	3,129·13
Do.	2190	Miner's Dream	..	76·00	35·53
		Voided Leases.			
Do.	(246), (450), (451), (459), (460), (494)	Associated Mt. Jackson G.M.S. (W.A.), Ltd.	..	801·50	224·71
Do.	(2284), (2285)	Athlone Reward Leases	..	105·00	104·81
Do.	(2547)	Best Known	..	220·80	33·35
Do.	(2336)	Bronzewing	..	44·50	60·03
Do.	(2271)	Effie's Reward	..	·25	3·70
Do.	(2362)	Flemington	4·36	..	..
Do.	(2505)	General Jackson	..	36·00	26·27
Do.	(2444)	Great Unknown, North	30·62	25·50	35·53
Do.	(2156)	Inglewood	..	13·50	8·96
Do.	(2597)	Just in Time	..	10·00	12·20
Do.	(2602)	Known Best	..	12·00	13·93
Do.	(2636)	Lone Chance	..	10·00	6·77
Do.	(2387)	Marda, East	..	7·50	12·01
Do.	(212), (217), (233), (397), (462)	Mt. Jackson G.M.S., Ltd. (1897)	..	9,537·00	6,210·61

Do.	(212), (217), (233), (397), (462)	(Mt. Jackson G.M.S., Ltd.)	..	15,054·00	*9,806·22
Do.	(212), (217), (397)	(Mt. Jackson G.M.S., Ltd.)	..	4,506·00	†3,297·25
Do.	(212), (217), (658), (659)	Mt. Jackson leases	..	250·00	119·55
Do.	(2397)	Mt. Jackson Wonder	..	120·00	44·27
Do.	(2713)	Newmarket	42·68	9·00	30·48
Do.	(2527)	Persian	..	16·00	31·96
Do.	(2300)	Queen of the Hills	..	8·00	20·85
Do.	(2548)	Standard	..	249·00	877·69
Do.	(2157)	Three Kings	..	10·00	12·31
Do.	(2614)	Titanic	..	26·00	24·92
Do.	(2564)	Victoria Reef	..	27·00	5·14
Do.	(2569)	Wellknown	..	6·00	6·96
Do.	(2310)	Yarbu	..	10·00	16·42
		Total output	**114·88**	**33,488·08**	**25,450·48**
Koolyanobbing	(641)	Chadwick's Reward	..	6·00	2·65
Do.	(909)	Jupiter	..	12·00	9·15
Do.	(917)	Saturn	..	28·00	2·07
Do.	(783)	St. Clair, No. 2 South	..	262·00	102·87
		Total output	..	**308·00**	**116·74**

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* Also 2,045·50 ozs. silver.

† Also 259·78 ozs. silver.

APPENDIX I.

TABLE SHOWING THE GOLD PRODUCTION OF THE YILGARN GOLDFIELD TO THE END OF THE YEAR 1916.

Mining Centre.	No. of Lease.	Registered Name of Company or Lease.	Total Production.				
			Alluvial.	Dollied and Specimens.	Ore treated.	Gold therefrom.	Silver.
			Fine ozs.	Fine ozs.	Tons (2,240lbs.)	Fine ozs.	Fine ozs.
Blackbourne ..	..	Voided leases	..	..	..	..	..
Do.	302	Royal Victoria South ..	..	..	84·00	43·25	..
Do.	557	King Edward VII.. ..	..	..	100·00	3·29	..
Do.	615	Millionaire	..	..	28·00	5·04	..
Do.	696	Blackburn South	..	..	92·00	32·93	..
Do.	671	Blackbourne..	..	..	492·00	142·37	..
Do.	887	Blackbourne..	..	..	486·50	114·49	..
Bullfinch	(2667)	Bullfinch East Extension ..	..	..	1,282·50	341·37	..
Do.	914, 915, 916, 926, 928, 942, 960	(Bullfinch leases)	..	..	16·00	39·20	..
Do.	914, 915, 916, 926, 928, 930, 942, 960	Bullfinch Proprietary (W.A.), Ltd.	..	..	1,027·52	10,958·88	..
Do.	..	Voided leases	..	..	247,393·42	106,445·38	16,442·43
Do.	962	Chaffinch: Great Chaffinch G.M. Co., M.L.	..	..	1·00	6·55	..
Do.	969, 970 ..	Bullfinch East G.M. Co., Ltd.	..	..	22·85	78·60	..
Do.	1263	Bullfinch Great Northern	..	..	16·00	2·91	..
Do.	2325	Golden Area	..	..	12·00	2·11	..

Do.	2337	Illawarra : Cosgrove Prospecting Syndicate	..	..	15·00	5·13	..
Do.	2404	Lady Agnes	..	..	201·40	184·03	..
Do.	2579	Derwent Jack	..	..	58·00	38·30	..
Do.	2779	Bell Bird	..	..	17·80	7·24	..
Corinthian ..	893	Corinthian	..	..	2,684·50	1,123·80	..
Do.	896, 934, 946,	Corinthian North G.Ms., Ltd.	..	..	131,222·00	27,564·32	..
Do.	..	Sundry claims	..	..	73·50	73·29	..
Do.	..	Voided leases	..	..	..	..	..
Do.	955	Pilot	..	..	65·00	10·75	..
Do.	1092	Corinthian Main Reef South	..	..	12·00	1·34	..
Do.	1391, 1393 ..	Babylonian G.M. Co., N.L. ..	..	..	72·50	57·96	..
Do.	1391, 1392, 1393	(Babylonia North leases)	..	..	371·00	312·83	..
Do.	1589	(Babylonia Extended) ..	..	..	28·00	6·84	..
Do.	1589, 1590 ..	Babylonian Extended G.M. Co., N.L.	..	..	53·00	16·02	..
Eenuin	2808	Star of Ennuin	..	..	118·16	342·89	..
Do.	—	Sundry claims	..	..	100·50	60·58	..
Do.	..	Voided leases	..	..	16·40	18·45	..
Do.	2865	Trig Hill	..	..	..	..	18·45
Golden Valley ..	(2755) ..	Deborah	..	..	122·50	182·27	2·00
Do.	2272	Glide Away	..	..	851·00	1,001·83	..
Do.	2948	Greenharp, New	..	..	148·50	197·99	..
Do.	3089	Lake View	..	..	34·00	36·50	..
Do.	2790	Manxman Consols	..	..	41·00	49·31	..
Do.	2389	(Marie's Find)	..	..	336·00	460·51	..
Do.	(2880)	Mount Kattrine	..	..	42·85	43·44	..
Do.	2389, 2390 ..	New Marie's Find G.Ms., N.L.	..	..	226·00	144·35	..
Do.	2994	Radio	..	..	42·00	244·65	..
Do.	2739	Rosalie	..	..	120·75	122·27	..
Do.	2653	Violet	..	..	83·64	56·12	..

TABLE SHOWING THE GOLD PRODUCTION OF THE YILGARN GOLDFIELD—*continued.*

Mining Centre.	No. of Lease.	Registered Name of Company or Lease.	Total Production.				
			Alluvial.	Dollied and Specimens.	Ore treated.	Gold therefrom.	Silver.
			Fine ozs.	Fine ozs.	Tons (2,240lbs.)	Fine ozs.	Fine ozs.
Golden Valley	..	Sundry claims	..	2·75	1,593·57	1,278·26	..
Do.	..	Voided leases	..	..	..	..	..
Do.	193	Kathleen	..	..	130·00	218·32	..
Do.	740	Last Trig	..	..	7·00	2·44	..
Do.	829	(Pioneer)	..	..	102·00	336·35	..
Do.	829, 920, 924, 1043	Pine Hill G.M. Co., N.L.	..	..	509·00	487·93	..
Do.	835	Violet	..	..	730·00	434·85	..
Do.	920	(Ada May)	..	..	115·00	179·99	..
Do.	922	Lily of the Valley	..	..	117·00	22·70	..
Do.	924	(Mountain Oaks)	..	..	302·50	418·46	..
Do.	927	Baby Queen	..	..	47·00	74·81	..
Do.	1008	Valley Wonder	..	..	14·00	5·36	..
Do.	1337	Golden Crown	..	..	40·00	5·19	..
Do.	1750	Budgeerigah	..	..	..	1·11	..
Do.	1751	Bullin Bullin	..	..	13·00	5·03	..
Do.	1807	Red Robin	..	..	25·50	11·44	..
Do.	1848	Marionette	..	..	14·00	11·95	..
Do.	2239	Welcome	..	..	89·00	39·77	..
Do.	2240	Sunset: The Sunset G.M. Co., Ltd.	..	..	67·00	14·30	..

Do.	2255	Manxman South Extended	..	..	126·00	112·50	..
Do.	2296	Manxman Main Lode ..	..	..	20·00	32·35	..
Do.	2297	Green Harp	..	..	46·00	53·21	..
Do.	2304	Bullwark	..	..	62·00	85·32	..
Do.	2357	Light Wing	..	..	4·50	1·75	..
Do.	2391	Rosalie	..	..	23·00	23·98	..
Do.	2435	Lady Mollie	..	..	17·25	6·76	..
Do.	2453	Golden Hole	..	..	19·50	16·24	..
Do.	2541, 2542 ..	New Green Harp leases ..	..	..	665·90	430·70	..
Do.	2553	Wainui	..	..	20·00	22·30	..
Do.	2559	Golden Valley	..	..	30·00	2·67	..
Do.	2595	Rosalie	..	..	64·00	126·57	..
Do.	2658	Lady Ellen	..	..	27·50	49·30	..
Do.	2690	Two Seas	..	..	79·00	77·92	..
Do.	2712	Sand King	..	..	66·00	29·12	..
Greenmount ..	**2992**	Searchlight	..	..	32·00	17·44	..
Do	**550**	(Sunbeam)	14·00	..	4,472·00	1,427·25	..
Do.	**550**	Sunbeam	..	..	200·00	100·14	..
Do.	**550, (565)** ..	(Sunbeam leases) ..	..	..	3,191·00	816·42	..
Do.	**2967**	Sunset	..	..	220·00	28·88	..
Do.	**536**	(Transvaal)	..	..	30,233·00	7,340·62	579·78
Do.	**536, 1358** ..	Transvaal leases ..	..	..	78·00	15·37	..
Do.	..	Sundry claims	..	4·12	632·50	263·70	..
Do.	..	Voided leases	..	..	..	..	..
Do.	693	Alligator	..	..	400·00	95·07	..
Do.	374	Ardath	..	..	75·00	18·37	..
Do.	694	Bulletin	..	..	440·00	131·12	..
Do.	793	Bulletin	..	..	42·00	7·42	..
Do.	603	Excelsior	..	..	18·00	4·90	..
Do.	580	Federal	..	..	80·00	13·42	..
Do.	684	Gem	..	..	77·00	9·47	..
Do.	756	Golden Fleece	..	..	355·00	62·50	..

TABLE SHOWING THE GOLD PRODUCTION OF THE YILGARN GOLDFIELD—*continued.*

Mining Centre.	No. of Lease.	Registered Name of Company or Lease.	Total Production.				
			Alluvial.	Dollied and Specimens.	Ore treated.	Gold therefrom.	Silver.
			Fine ozs.	Fine ozs.	Tons. (2,240lbs.)	Fine ozs.	Fine ozs.
Greenmount	604	Great Southern	..	..	135·00	23·48	..
Do.	713	Great Surprise	..	..	..	35·37	..
Do.	503, 535, 555	(Greenmount G.Ms., Ltd.)	..	..	5·00	2·11	..
Do.	503, 535, 555	Greenmount Mines, N.L.	..	..	64,186·00	15,788·99	..
Do.	591	Imperial	..	..	133·00	30·92	..
Do.	566	Little Wonder	..	..	71·00	19·92	..
Do.	622	Lord Roberts	..	..	237·00	73·11	..
Do.	1220	Lord Roberts	..	..	56·00	9·88	..
Do.	625	Madge	..	..	65·00	16·14	..
Do.	599	Port Royal	..	..	71·00	13·87	..
Do.	590	Rand	..	..	179·00	43·05	..
Do.	640	Rand	..	..	26·00	5·44	..
Do.	565	(Royal George)	..	..	1,806·00	602·41	..
Do.	744	Southern Cross Boulder	..	..	214·00	69·76	..
Do.	564	St. George	..	..	204·00	56·43	..
Do.	655	Sunbeam North	..	..	10·00	·87	..
Do.	492, 511	Transvaal	..	..	692·00	198·09	..
Do.	511, 516	Transvaal	..	..	310·00	61·23	..
Do.	503	(United Australia)	..	..	410·00	120·15	..
Hope's Hill	2544	Colleen Bawn	..	..	287·20	1,119·77	..
Do.	..	Sundry claims	..	25·38	1,317·50	467·40	..

Do.	.. ..	Voided leases	..	..	..	..	..	..
Do.	500	Australia United	..	..	..	60·00	0·81	..
Do.	1052	Cross	..	..	..	15·00	17·45	..
Do.	932	Debtors Friend	..	..	..	150·00	20·20	..
Do.	2502	Great Boulder, No. 2 ..	..	..	..	58·00	25·42	..
Do.	1727, 1771 ..	Hopefinch leases	..	..	..	107·00	10·41	..
Do.	795	Hope's Hill	..	..	..	357·00	152·99	..
Do.	19, 52, 288, 360, 480	Hope's Hill G.M. Co., Ltd. ..	..	..	..	124,825·00	31,671·83	..
Do.	880	Hope's Hill North ..	..	..	..	165·00	31·83	..
Do.	895	Hope's Hill Perseverance	..	..	..	426·50	459·37	..
Do.	809	Hope Still	..	..	..	38·00	6·17	..
Do.	814	Lady Kathe..	..	..	..	30·00	7·97	..
Do.	2524	Lady Kathe..	..	..	..	45·00	7·76	..
Do.	2639	Last Hope	..	..	..	34·00	7·42	..
Do.	877	Maud	..	..	..	228·00	53·01	..
Do.	703	Mellor's Hill	..	..	..	90·00	53·14	..
Do.	661	Mount Victor	..	..	..	85·00	16·22	..
Do.	899	Norwood	..	..	..	40·00	53·41	..
Do.	2523	Parisian	..	..	..	797·50	565·74	..
Do.	1432	Phoenix	..	..	..	1,442·50	532·93	..
Do.	2571	Phoenix South	..	..	..	30·00	3·90	..
Do.	801	Pryoress	..	..	..	104·00	67·61	..
Do.	620	Railway	..	..	..	81·35	20·41	..
Do.	628	Railway South	..	..	..	105·00	22·42	..
Do.	1288	Red Wings	..	..	..	8·00	1·19	..
Do.	2354	Renegade	..	..	..	123·00	21·85	..
Do.	815	Reward South	..	..	..	20·00	2·44	..
Do.	921	Rodda's Reward	..	..	..	312·00	42·13	..
Do.	2906	Try Again	..	..	..	88·00	12·75	..
Do.	910	Willbee	..	..	..	20·00	2·77	..
Kennyville ..	776	Cornishman	..	..	13·18	2,048·00	1,780·53	..
Do.	570	(Great Leviathan)	..	..	..	3,821·85	2,948·67	..

TABLE SHOWING THE GOLD PRODUCTION OF THE YILGARN GOLDFIELD—*continued.*

Mining Centre.	No. of Lease.	Registered Name of Company or Lease.	Total Production.				
			Alluvial.	Dollied and Specimens.	Ore treated.	Gold therefrom.	Silver.
			Fine ozs.	Fine ozs.	Tons. (2,240lbs.)	Fine ozs.	Fine ozs.
Kennyville	**570**	Great Leviathan	..	..	4,073·00	3,192·32	..
Do.	**570**	(Great Leviathan: Northern Blocks Syndicate, Ltd.)	..	..	10,705·00	2,974·64	..
Do.	**911**	Trafalgar	..	..	1,337·00	1,111·52	..
Do.	..	Sundry claims	..	..	277·00	151·42	..
Do.	2574	Bournville	..	..	83·00	29·35	..
Do.	813	Catherine	..	..	399·50	161·63	..
Do.	2876	Catherine	..	..	135·00	41·23	..
Do.	828	Croesus	..	..	31·00	5·81	..
Do.	2545	Emperor	..	..	53·00	8·04	..
Do.	856	Glen Dower	..	..	237·00	150·09	..
Do.	2539, 2568	Mornington Prospecting Syndicate, N.L.	..	..	20·00	3·18	..
Do.	683	New Chum	..	..	67·00	6·74	..
Do.	582	Yilgarn Perseverance	..	..	158·00	77·40	..
Do.	..	Voided leases	..	..	..	..	..
Koolyanobbing	641	Chadwick's Reward	..	..	6·00	2·65	..
Do.	909	Jupiter	..	..	12·00	9·15	..
Do.	917	Saturn	..	..	28·00	2·07	..
Do.	783	St. Clair. No. 2 South	..	..	262·00	102·87	..
Marvel Loch	**923**	Bohemian	..	17·44	3,349·00	3.263·85	..

Do.	1689	(Bronco)	..	..	217·00	22·17	..
Do.	1689	Bronco: Bronco Horseshoe Proprietary Mining Co., N.L.	..	..	1,770·00	501·70	..
Do.	(1465)	(Comet)	..	..	6,673·00	5,040·34	..
Do.	(768)	(Donovan's Find)	..	..	1,768·00	1,909·43	..
Do.	(768)	Donovan's Find: Greenmount Mines, N.L.	..	..	2,276·00	1,117·44	..
Do.	1463	Eclipse	..	6·87	2,003·00	1,474·38	..
Do.	3006	Firelight	..	..	15·00	26·20	..
Do.	(820)	Gentle Annie	..	..	1,627·00	670·64	..
Do.	(2885)	Golden Cube	..	..	65·00	32·31	..
Do.	2656	Golden Dream	..	..	40·00	52·65	..
Do.	719	(Great Victoria)	..	..	1,356·00	281·53	..
Do.	719, 944, 945, 1227, 1228, 1606	Great Victoria leases	..		60,988·00	7,056·80	..
Do.	(2907)	Jacoletti No. 1	..	..	367·00	164·72	..
Do.	(714)	(Marvel Loch)	..	..	500·00	316·81	..
Do.	(714), (723), (822), (869)	Marvel Loch G.M. Co., N.L.	..	..	49,235·50	18,590·18	379·96
Do.	852	May Queen	..	4·07	626·50	3,613·48	..
Do.	(808), (838), (948), (949) (950), (951)	(Mountain Queen leases)	..	..	748·00	208·39	..
Do.	(808) (838), (948), (949), (950), (951), (2543), (2754)	Mountain Queen, Ltd.	..	..	103,909·00	29,222·44	376·17
Do.	(665)	(Never Never)	..	..	29,395·00	7,709·26	..
Do.	3030	Never Never	..	..	85·00	48·25	..
Do.	(2979)	Newry	..	..	159·00	27·16	..
Do.	3017	Pro Patria	..	..	307·00	362·14	..
Do.	1011	Rising Star	..	..	140·00	11·48	..

TABLE SHOWING THE GOLD PRODUCTION OF THE YILGARN GOLDFIELD—*continued.*

Mining Centre.	No. of Lease.	Registered Name of Company or Lease.	Total Production.				
			Alluvial.	Dollied and Specimens.	Ore treated.	Gold therefrom.	Silver.
			Fine ozs.	Fine ozs.	Tons	Fine ozs.	Fine ozs.
Marvel Loch	**2993**	Sandfly	..	..	310·00	302·30	..
Do.	**2998**	St. George	..	..	708·00	294·90	..
Do.	**3011**	Victory	..	..	145·00	83·63	..
Do.	**(665), (765)**	Yilgarn G.M. Co., Ltd.	..	..	4,353·00	749·63	14·90
Do.	..	Sundry claims.	7·72	68·81	5,425·75	3,371·26	..
Do.	..	Voided leases					
Do.	2484	Bee	..	..	68·00	36·16	..
Do.	774	Alpha	..	..	34·00	26·19	..
Do.	2530	Beta	..	..	40·00	5·76	..
Do.	2538	Cadonia	..	..	40·00	43·19	..
Do.	R.C. 656	Christmas Gift	..	..	452·00	325·83	..
Do.	819	Christmas Gift	..	..	49·00	16·76	..
Do.	2588	Dalmore	..	..	14·00	38·40	..
Do.	925	Dell	..	..	100·00	62·81	..
Do.	884	Democrat	..	..	289·00	154·50	..
Do.	869	(Evelen's Eden)	..	..	104·00	44·29	..
Do.	717	Evelen's Eden	..	..	622·00	349·17	..
Parker's Range	**2978**	Gift	..	..	96·00	71·39	..
Do.	**2656**	Golden Dream	..	37·10	366·00	583·20	..
Do.	(2606)	King of the Range	..	..	331·00	624·06	..
Do.	(2905)	Lord Kitchener	..		16·00	3·11	

Do.	**2801**	Scots Greys	..	..	10·00	6·25	
Do.	**2546**	South Side	..	4·82	112·00	42·21	..
Do.	**724**	(Spring Hill)	..	..	3,232·00	607·21	..
Do.	**724, (760)** ..	(Spring Hill leases) ..	..	..	8,910·00	2,215·59	..
Do.	**724, 2633** ..	Spring Hill G.M. Co.. N.L. ..	..	..	1,176·00	112·88	..
Do.	**2806**	Star of the Range ..	..	..	92·50	189·21	..
Do.	**2951**	White Horseshoe	..	..	541·75	484·02	..
Do.	..	Sundry claims	..	..	1,576·75	1,030·53	..
		Voided leases	..	..	..	..	..
Do.	485, 508 ..	Australia	..	..	3,218·00	1,666·37	..
Do.	771	Battler's Hill	..	..	6·00	16·89	..
Do.	515	Blue Hill	..	..	80·00	366·47	..
Do.	(515), 520 ..	Blue Hill	..	..	1,071·00	1,627·94	..
Do.	524	Blue Hill No. 1 North ..	..	..	20·00	7·59	..
Do.	830	Brilliant	..	..	278·50	163·22	..
Do. ..	2785	Briton	..	..	51·00	46·29	..
Do.	216	Passby: Carlyle G.M. Co., Ltd.	..	..	36·00	47·18	..
Do.	746	Dulcie Jean	..	..	108·75	161·35	..
Do.	751	Ell Ess Dee	..	..	26·00	28·61	..
Do.	2128	Ell Ess Dee	..	..	11·00	3·24	..
Do.	491	Enterprise	..	..	750·00	147·15	..
Do.	736	Garibaldi	..	..	70·50	38·98	..
Do.	594	Golden Cube	..	..	600·00	672·09	..
Do.	707	Golden Cube	..	..	1,344·00	518·80	..
Do.	263	Golden Key Extended ..	..	..	20·00	11·45	..
Do.	2512	Golden Links	..	..	13·00	12·81	..
Do.	698	Golden Mile G.M. Co., Ltd. ..	..	..	33·00	3·75	..
Do.	761	Golden Rod	..	..	137·00	62·10	..
Do.	310	Good Brothers	..	..	35·00	20·74	..
Do.	(491), 528 ..	Gordon Highlander ..	..	..	116·00	92·36	..
Do.	573	Gordon Highlander ..	..	..	60·00	24·33	..
Do.	668	Gordon Highlander ..	..	..	117·00	44·42	..
Do.	547	Havelock	..	..	30·00	12·24	..

TABLE SHOWING THE GOLD PRODUCTION OF THE YILGARN GOLDFIELD—*continued.*

Mining Centre.	No. of Lease.	Registered Name of Company or Lease.	Total Production.				
			Alluvial.	Dollied and Specimens.	Ore treated.	Gold therefrom.	Silver.
			Fine ozs.	Fine ozs.	Tons (2,240lbs.)	Fine ozs.	Fine ozs.
Parker's Range	240	Just in Time	..	..	15·00	21·71	..
Do.	2649	Kia Ora	..	..	84·00	37·88	..
Do.	2503	Lone Hand	..	..	23·00	3·33	..
Do.	574	Lucky Hit	..	..	101·00	94·57	..
Do	908	L.S.D.	..	..	140·00	33·84	..
Do.	443	Lydia	..	..	10·00	·94	..
Do.	1099	(McIntosh)	..	..	110·00	54·89	..
Do.	797	McIntosh	..	..	172·00	101·66	..
Do.	518	McIntosh G.M. Co., Ltd.	..	..	29·00	14·90	..
Do.	827	New Year's Gift	..	..	1,676·00	416·32	..
Do.	1099, 1566	Parker's Range G.Ms., N.L.	..	..	213·50	209·55	..
Do.	769	Piemonte	..	..	259·50	44·93	..
Do.	250	Queen of Sheba	..	..	2·00	1·25	..
Do.	489	Queensland Consols	..	..	160·00	41·77	..
Do.	(T.A. 9) 485	Queensland United: Australian Mines Agency, Ltd.	..	..	158·00	559·72	..
Do.	1688	Raven	..	..	25·00	4·71	..
Do.	2683	Referenda	..	..	66·00	148·54	..
Do.	2324	Searchlight North: Yarloop Prospecting Syndicate	..	..	150·50	31·77	..

Do.	1770	Searchlight : Ziggler Prospecting and Option Syndicate, N.L.	..	..	57·50	40·84	
Do.	2611	Snowdrop	..	..	155·00	204·25	..
Do.	2676	South Side Extended ..	..	..	36·00	20·17	..
Do.	2670	Sphinx	..	..	34·00	33·11	..
Do.	2682	Star of the Range ..	..	..	140·00	146·95	..
Do.	1425	Splendid Kingfisher: King of the Range G.M. Co., Ltd.	..	..	52·00	85·08	..
Do.	532	Triumph	..	..	248·00	77·18	..
Do.	642	Triumph	..	..	83·00	42·57	..
Do.	2974	Evelen's Eden	..	..	40·00	13·04	..
Do.	753	Exhibition	..	..	859·00	278·64	..
Do.	823	Exhibition	..	..	1,111·00	430·83	..
Do.	858	Firelight	..	..	200·00	49·80	..
Do.	779	Frances Firness	..	..	1,825·00	826·47	..
Do.	825	Geelong	..	..	155·00	102·93	..
Do.	2609	Geelong	..	..	222·50	142·01	..
Do.	2563	Golden Gate	..	..	18·00	3·74	..
Do.	851	Green Jacket	..	..	8·00	6·37	..
Do.	490, 517, 558, 559, 804	Jacoletti G.Ms., Ltd.	..	..	6,716·00	2,929·74	..
Do.	821	Lady Agnes	..	..	77·00	14·72	..
Do.	490, 517, 558, 559	(Lady Loch Mines, Ltd.) ..	..	..	2,091·00	674·01	..
Do.	739	Marvel Loch North ..	..	..	626·00	398·76	..
Do.	2662	Marvel Loch North ..	..	..	96·00	49·52	..
Do.	792	Mountain King	..	..	387·00	245·73	..
Do.	1603	Mountain King	..	..	205·00	137·50	..
Do.	2684	Mountain King	..	..	188·00	172·30	..
Do.	805	Mountain Prince	..	..	255·00	106·84	..
Do.	1156	Mountain Prince North ..	..	..	60·00	11·67	..
Do.	2490	New Democrat	..	..	316·50	241·71	..

TABLE SHOWING THE GOLD PRODUCTION OF THE YILGARN GOLDFIELD—*continued.*

Mining Centre.	No. of Lease.	Registered Name of Company or Lease.	Total Production.				
			Alluvial.	Dollied and Specimens.	Ore treated.	Gold therefrom.	Silver.
			Fine ozs.	Fine ozs.	Tons (2,240lbs.)	Fine ozs.	Fine ozs.
Parker's Range ..	824	Newry	..	..	990·50	218·36	..
Do.	812	Pariah	..	..	120·50	89·61	..
Do.	807	Queen Mab	..	..	280·00	125·79	..
Do.	2575	Saint George	..	..	1,266·00	443·93	..
Do.	839	Scorpio	..	..	1,754·50	1,309·37	..
Do.	2522	Southern Kingfisher ..	..	..	114·00	13·15	..
Do.	1435	Starfinch	..	..	149·00	58·10	..
Do.	490, 517, 558, 559	(Turnbull's leases)	..	..	2,143·00	1,481·72	..
Do.	1452	Undaunted	..	..	834·00	249·41	..
Mt. Jackson ..	**1979**	Allen's Find..	..	..	1,511·05	777·82	..
Do.	**1933**	Butcher Bird No. 1 ..	..	..	2,668·50	1,977·59	..
Do.	**2053**	Great Unknown	..	37·22	1,225·43	3,469·92	..
Do.	**(2190)**	Miner's Dream	..	..	425·00	129·34	..
Do.	**(2826)**	Unknown South	..	..	19·00	15·62	..
Do.	..	Voided leases	..	77·66	30,914·55	21,046·90	2,305·28
Do.	..	Sundry claims	4·42	25·43	1,418·25	917·31	..
Do.	246, 450, 451, 459, 460, 494	Associated Mt. Jackson G.Ms. (W.A.), Ltd.	..	..	801·50	224·71	..

Do.	2[illegible]47	Best Known	..	..	[illegible]0·80	3[illegible]·3[illegible]	..
Do.	2330	Bronzewing	..	..	44·50	60·03	..
Do.	2271	Ellie's Reward	..	..	·25	3·70	..
Do.	2302	Flemington	..	..	..	4·36	..
Do.	2505	General Jackson	..	..	36·00	26·27	..
Do.	2444	Great Unknown, North ..	..	..	25·50	66·15	..
Do.	2156	Inglewood	..	..	13·50	8·96	..
Do.	2507	Just in Time	..	..	10·00	12·20	..
Do.	2602	Known Best	..	..	12·00	13·93	..
Do.	2636	Lone Chance	..	..	10·00	6·77	..
Do.	2387	Marda East	..	..	7·50	12·01	..
Do.	212, 217, 233, 397, 462	Mt. Jackson G.Ms., Ltd. (1897)	..	..	9,537·00	6,210·61	..
Do.	212, 217, 233, 397, 462, 658, 659	(Mt. Jackson G.Ms., Ltd.) ..	..	..	15,054·00	9,806·22	..
Do.	212, 217, 397, 658, 659	Mt. Jackson G.Ms., Ltd. ..	..	..	4,506·00	3,297·25	..
Do.	212, 217, 658, 659	Mt. Jackson leases.. ..	..	..	250·00	119·55	..
Do.	2397	Mt. Jackson Wonder ..	..	..	120·00	44·27	..
Do.	2713	Newmarket	..	..	9·00	73·16	..
Do.	2527	Persian	..	..	16·00	31·96	..
Do.	2300	Queen of the Hills.. ..	..	..	8·00	20·85	..
Do.	2548	Standard	..	..	249·00	877·69	..
Do.	2157	Three Kings	..	..	10·00	12·31	..
Do.	2614	Titanic	..	..	26·00	24·92	..
Do.	2564	Victoria Reef	..	..	27·00	5·14	..
Do.	2569	Wellknown	..	..	6·00	6·96	..
Do.	2310	Yarbu	..	..	10·00	16·42	..
Mt. Rankin ..	..	Sundry claims	..	..	170·00	54·38	..
Do.	..	Voided leases	..	..	..	..	..
Do.	416	Mt. Rankin	..	..	56·00	21·96	..

TABLE SHOWING THE GOLD PRODUCTION OF THE YILGARN GOLDFIELD—*continued.*

Mining Centre.	No. of Lease.	Registered Name of Company or Lease.	Total Production.				
			Alluvial.	Dollied and Specimens.	Ore treated.	Gold therefrom.	Silver.
			Fine ozs.	Fine ozs.	Tons (2,240lbs.)	Fine ozs.	Fine ozs.
Mt. Rankin ..	525	Mt. Rankin	..	..	196·00	56·58	..
Do.	870	No Trumps	..	..	244·00	52·67	..
Southern Cross ..	(2744)	Central	..	..	273·00	62·50	..
Do.	3010	Central	..	..	167·00	51·25	..
Do.	3016	Central Extended	..	..	15·00	9·97	..
Do.	(2714)	Fraser's North Extended ..	..	..	10·00	10·37	..
Do.	(2342)	Haddon Consolidated ..	..	..	3,810·50	1,320·84	..
Do.	(2416)	(Maori Lass)	..	..	250·00	52·31	..
Do.	(2416)	Maori Lass, Ltd.	..	..	483·00	54·47	..
Do.	2987	Sunset	..	..	80·00	9·47	..
Do.	..	Sundry claims	3·73	595·45	2,292·10	684·38	..
Do.	..	Voided leases	..	..	..	..	..
Do.	652	Alison Brown	..	..	10·00	1·77	..
Do.	2529	Allerton	..	..	142·00	50·18	..
Do.	579	Auraria	..	..	15·00	4·45	..
Do.	473	Ave Maria	..	..	50·00	10·18	..
Do.	663	Birthday Gift	..	..	73·00	17·28	..
Do.	738	Brown Hill	..	..	176·00	38·62	..
Do.	2572	Central	..	..	47·00	29·61	..
Do.	279, 890 ..	(Central G.M. Co., N.L.)			44,958·00	19,702·85	..

Do.	(407), 321	Comet	..	..	3,161·00	570·13	..
Do.	450	Day Dawn G.M. Co., N.L.	..	..	72·50	8·34	..
Do.	556	Eureka Boulder	..	..	30·00	7·22	..
Do.	607	Excelsior	..	..	788·00	465·82	..
Do.	2423	Excelsior No. 2	..	..	17·00	1·12	..
Do.	889 (late 13)	(Fraser's G.M. Co., N.L.)	..	..	151,771·00	61,870·33	..
Do.	888, 889	Fraser's G.M. Syndicate	..	..	287·25	681·79	..
Do.	888 (late 29)	(Fraser's South G.M. Co., N.L.)	..	..	48,233·00	20,013·23	..
Do.	256, 496, 554, 562	Fraser's South Extended G.M. Co., Ltd.	..	..	43,747·68	18,433·55	..
Do.	230, 253	Golden Pig leases: Water Trust and Public Crushing Co. of W.A., Ltd.	..	..	3,889·35	944·83	..
Do.	448 (late 286)	Golden Pig North	..	..	20·00	4·70	..
Do.	576	Golden Pig North	..	..	94·00	20·38	..
Do.	653	Golden Pig North	..	..	15·00	2·57	..
Do.	670	Golden Pig North	..	..	45·00	5·95	..
Do.	449	Golden Rock	..	..	12·00	1·50	..
Do.	470	Great Southern	..	..	380·00	321·79	..
Do.	552	(Haddon)	..	..	680·00	145·01	..
Do.	552	Haddon	..	..	..	8·64	..
Do.	532, 611	(Haddon leases)	..	..	7,178·00	1,396·90	..
Do.	529, 551	Hatt & Lang's leases	..	..	6,601·00	1.898·54	..
Do.	501	Homeward Bound	..	..	758·85	218·94	..
Do.	673	Ine Zella	..	..	214·00	47·48	..
Do.	526	Irene	..	..	196·00	43·40	..
Do.	1259	King of the Cross	..	..	10·00	·79	..
Do.	1056	(Lady Edeline)	..	..	12·00	13·87	..
Do.	749, 1056, 1543, 2218	Lady Edeline G.M. Co., N.L.	..	..	12·00	148·11	..
Do.	1042	Lord Cardigan	..	..	432·00	127·61	..
Do.	613	Lord Cardigan	..	..	913·00	232·93	..
Do.	560	Northern Star	..	..	112·00	36·43	..

TABLE SHOWING THE GOLD PRODUCTION OF THE YILGARN GOLDFIELD—*continued.*

Mining Centre.	No. of Lease.	Registered Name of Company or Lease.	Total Production.				
			Alluvial.	Dollied and Specimens.	Ore treated.	Gold therefrom.	Silver.
			Fine ozs.	Fine ozs.	Tons (2,240lbs.)	Fine ozs.	Fine ozs.
Southern Cross ..	647	Northumberland	..	..	35·00	7·24	..
Do.	280	No. 1 Central Extended G.M. Co., N.L.	..	..	10,374·00	4,261·34	..
Do.	575	Pendrea	..	..	25·00	5·22	..
Do.	475	Perseverance	..	..	..	1,089·17	..
Do.	1889	Pretoria	..	..	127·00	32·26	..
Do.	681	Pride of the Hills	..	..	139·00	22·51	..
Do.	2651	Queen Ann	..	..	388·00	129·23	..
Do.	·529	(Reward)	..	..	2,300·00	1,664·48	..
Do.	737	Reward	..	..	46·00	64·10	..
Do.	467	Southern Cross	..	..	167·00	91·05	..
Do.	454	Southern Cross Boulder ..	..	..	50·00	9·87	..
Do.	644	Southern Cross Boulder ..	..	..	10·00	3·43	..
Do.	612	Southern Cross Extended	..	..	53·00	6·41	..
Do.	611	(Take Down)	..	..	16·00	13·79	..
Do.	252	Tarcoola	..	..	11·00	16·47	..
Do.	568	Tarcoola	..	..	60·00	8·29	..
Do.	276	Tarcoola North	..	..	50·00	21·33	..
Do.	631	William Tell	..	..	27·00	5·04	..
Do.	567	Wimmera	..		2,268·00	345·87	

Do.	2182	Voss	..	..		[illegible]·00	8·04	..
Do.	2051	Vilgarn Consols G.M. Co., N.L.	..	..		508·50	155·12	..
Weston's	2769	(Battler)	..	..		115·00	170·04	..
Do.	(2814)	Battler West	..	..		11·00	8·35	..
Do.	2180	(Edna May)	..	..		581·00	910·27	..
Do.	2769	Edna May Battler G.M. Co., N.L.	..	..		1,988·00	1,909·30	..
Do.	2291, 2585, 2615	Edna May Central G.Ms., N.L.	..	..		64,869·00	19,926·45	19·38
Do.	2570, 2617, 2644	Edna May Consolidated G.M. Co., N.L.	..	..		668·00	201·16	..
Do.	2180, 2605 ..	Edna May G.M. Co., N.L. ..	..	..		110,483·00	110,021·13	..
Do.	2775	Emma May	..	..		40·00	20·31	..
Do.	3026	Florence Mabel	..	..		17·00	19·94	..
Do.	3004	Great Battler	..	..		50·50	68·86	..
Do.	(2086), 2087, 2088, (2635)	Greenfinch Proprietary G.M., Co., N.L.	..	..		7,875·00	2,853·95	..
Do.	2807	Hill End	..	..		194·00	136·87	..
Do.	(3020)	Irene	..	..		15·00	24·81	..
Do.	2291	(Myrtle Central)	..	..		751·00	243·96	..
Do.	2168, 2238 ..	Myrtle Consols leases ..	..	..		1,252·00	1,204·35	..
Do.	2570	(Myrtle East)	..	..		202·00	116·12	..
Do.	2816	Pertha M.	..	..		392·00	263·41	..
Do.	(2867)	Western Options	..		4·06	10·00	2·88	..
Do.	2724	(Weston's Reward)	..	..		35·00	57·24	..
Do.	2724, 2761 ..	Weston's Reward G.Ms., N.L.	..	..		473·50	424·66	..
Do.	..	Sundry claims	..		11·04	728·75	710·05	..
		Voided leases.						
Do.	2361	Independent	..	..		28·00	18·47	..
Do.	2241	Jessie No. 1	..	..		16·50	18·24	..
Do.	2092	Little Mary	..	..		16·00	3·47	..
Do.	2565	Nevertire	..	..		12·00	2·13	..
Do.	2083	Christmas Birthday Central	..	..		20·75	33·56	..
Do.	2577	Diorite Queen	..	..		5·00	1·20	..
Do.	2688	Elsie	..	..		73·50	22·19	..

Table showing the Gold Production of the Yilgarn Goldfield—*continued.*

Mining Centre.	No. of Lease.	Registered Name of Company or Lease.	Total Production.				
			Alluvial.	Dollied and Specimens.	Ore treated.	Gold therefrom.	Silver.
			Fine ozs.	Fine ozs.	Tons.	Fine ozs.	Fine ozs.
		From Goldfield generally:					
		Sundry parcels treated at:					
		Australia Battery	..	..	38·00	124·94	..
		Donovan's Find Battery	..	..	..	2,536·33	..
		Fraser's G.M. Works	..	..	..	583·63	..
		Fremantle Smelting Works	..	..	21·28	592·34	33·90
		Great Victoria Cyanide Works	..	..	..	3,295·38	..
		Greenfinch Proprietary G.M. Works ..	..	..	..	2,187·86	..
		Hopes Hill Cyanide Works	..	..	..	1,174·57	..
		Jacoletti Works	..	..	..	2,062·82	..
		Marvel Loch Mining Co., N.L.	..	..	..	3,633·77	..
		Never Never Works	..	..	..	146·00	..
		Spring Hill Works	..	..	..	266·26	..
		Sunbeam Works	..	..	8·00	5,242·28	..
		Violet Works	..	..	..	923·51	..
		Various Works	..	..	59·00	11,053·60	2·64
		Reported by Banks and Gold Dealers ..	22·05	3·53	..	..	..
		Total	**89·88**	**1,394·70**	**1,652,337·97**	**756,481·84**	**20,886·86**

APPENDIX II.

THE KOOLYANOBBING IRON ORE DEPOSITS.

By T. Blatchford.

On account of the discovery of some very high-grade micaceous-hæmatite iron ore in the vicinity of the Trig. Station on the Koolyanobbing Range, a second inspection was made, the primary object being to try and locate the boundaries of the deposit and, if possible, ascertain whether any other deposits of a similar nature occurred in the vicinity.

The hæmatite deposit was found to be a lens of ore, the major axis of which was 170 feet and the minor 70 feet. From the sides of this lens veinlets of ore extend into the surrounding rock. Such were not included in the area marked out as the lens.

The ore in the lens is massive hæmatite, mixed to a certain extent with fragments of the quartzite, the staple rock of the range. The occurrence is, apparently, secondary deposition of iron ore in a brecciated zone. In consequence of the included foreign siliceous material the value of the ore as a commercial product is considerably lessened, which, taken in conjunction with its apparently limited area, detracts from the value of the deposit. One point in favour of greater quantities of ore being found than appear at the surface is the extreme magnetism where no iron shows at the surface.

This magnetism is particularly noticeable at and near the Trig. Station, the variation in the needle being so pronounced as to render magnetic readings from this point worthless.

As may be seen from the accompanying analysis the picked ore from the hæmatite lens is practically free from sulphur and phosphorus, whilst the contained silica is very low too.

Analysis of micaceous hæmatite, Koolyanobbing:—

G.S.M. $\frac{1}{51}$.		G.S.L. 7458D.
Fe_2O_3	98·75%	Fe 69·13%
SiO_2	1·04	
P	·016	
S	trace	
Ignition loss	·39	

Analyst, D. G. MURRAY.

Lying to the west and abutting on the hæmatite lens a deposit of brown iron ore was noticed. The apparent course of this deposit was from the gnamma-hole on the flat, past the Trig. Station and extending to the bluff south of the Trig. Station.†

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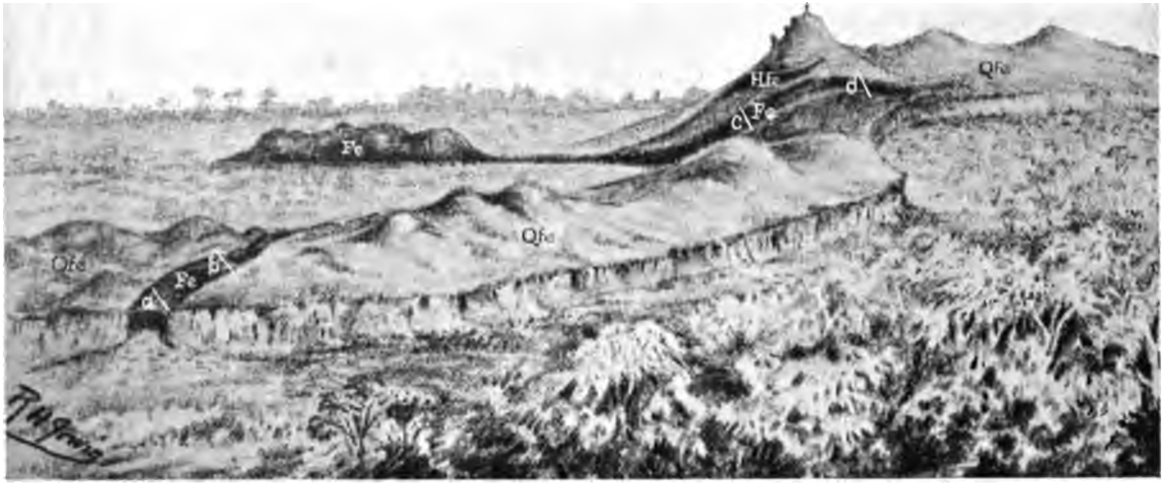
† Plate XIX.



General Sketch of Koolyanobbing, illustrating occurrence of iron-bearing deposits.

Two samples were broken from the outcrops of this lode—one (C) immediately to the west of the Trig., and the other (D) near the southern extremity.

The samples were broken over a width of 200 and 150 feet respectively.

Under the present conditions it is impossible to be too definite as to the occurrence, for the surface is very much masked by the débris of the higher portion of the range. It would appear, however, that an extensive faulting has occurred and in the fault this extensive iron deposit has been formed. Another similar lode has been located north-west from the Trig.* Two samples were taken from this deposit also. Of these, the first was taken across the dip on the face of the escarpment, the total width sampled being 150 feet. Sample (A). Another (B) was taken 500 feet east of the first, over a width of 200 feet.

The results from these four samples were remarkably regular and gave a high percentage of metallic iron. The percentages of silica, phosphorus, and sulphur were also very low. Unfortunately, time would not permit of an investigation of the whole of the range, but judging by the faulting marked out by my colleague during his inspection, it is highly probable that similar deposits could be located if the range were thoroughly inspected. The sampling, it should be noted, was not undertaken to prove the value of the deposits, but only as a preliminary inspection to ascertain whether they were worthy of further notice, in the view of a possible opening up iron deposits for commercial uses.

However gratifying the results may seem, there is still much work to be executed before any definite data can be put on paper. The preliminary assays should first be checked and an attempt made to find other, may be, larger deposits which may be even more accessible than the present ones under notice. If such investigations proved satisfactory the expenditure of capital to prove the extent of the deposits would then be warranted. This could be done in three ways: Shaft sinking and cross-cutting, driving adits along the lodes from the sides of the range, or boring. Several factors arise in deciding the best of these three.

In the first place, before an iron lode can be considered a commercial proposition the following must be taken into consideration:—

Extent of deposit, grade of ore, working costs (including freights).

From the preliminary sampling the grade appears to be high and very regular, and may be considered of secondary importance to tonnage. For this reason it appears that boring would be the proper method to adopt, as the deposits could be proved to much greater depths by boring, for the same expenditure, and at the same time fair samples taken from the cores. Unless mining operations were extended to considerable depths they would not be of any use in working the deposits, for if at any time they were mined, open cutting or quarrying would be resorted to for at least 100 to 200 feet from the outcrops.

---

*Plate XIX.

As regards transportation, a branch line from the main trunk line could easily be laid over level country, the total distance being not more than probably 30 to 35 miles, the connection being at Southern Cross, or thereabouts, a distance of, roughly, 240 miles from Fremantle. The ore, being at no great distance from the trunk line, would make excellent back loading.

"Analyses of four samples of iron ore from Koolyanobbing:—

G.S.L., No.	9618	9619	9620	9621
Mark	A	B	C	D
	%	%	%	%
Fe_2O_3	90·30	88·33	86·76	86·44
equal to				
Fe	63·21	61·85	60·73	60·51
SiO_2	2·02	4·78	2·40	3·08
S	·06		·04	
P	·01		·006	
Gold (per ton)	trace	trace	10grs.	16grs.

"The sulphur and phosphorus were determined in mixtures of equal proportions of the component samples. The undetermined is mainly combined water.

"These are high-grade brown iron ores of the non-phosphoric class, suitable for the manufacture of steel by the acid Bessemer, Open Hearth, or Electric processes.

"The principal constituents are:—

Of (1) and (2) Turgite and Goethite.
Of (3) and (4) Goethite."

(Sgd.) EDWARD S. SIMPSON,
Mineralogist and Chemist.

14th September, 1916.

SECTION C.

THE MINERALS OF WESTONIA.

By Edward S. Simpson.

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THE MINERALS OF WESTONIA.

By Edward S. Simpson.

The following notes on the minerals to be found at or near the gold-mining centre of Westonia are based mainly on the collections made by Mr. T. Blatchford, Assistant Geologist, during the progress of a geological survey of this area. To him I am indebted for much information regarding the modes of occurrence in the field. I have also had access to specimens collected by Mr. H. G. Stokes, manager of the Edna May Golden Point Mine, to whose enthusiasm as a collector of minerals is due the discovery of the unusual variety of wulfenite described in the following pages.

The rock-forming minerals of Westonia are in the main identical with those of other gold-mining areas of the central plateau of Western Australia whose mineralogy has been studied in detail, the prevailing rock types being microcline granite and hornblendic greenstones. The large development of biotite in the granitic rocks and their offshoots, and to some extent in the altered greenstones, is a point of distinction, as also the presence of unaltered olivine in one of the smaller rock masses. Turning to metamorphic rock minerals, we find tourmaline unusually rare, but garnet, andalusite and sillimanite present, all three distinctly uncommon in our plateau goldfields. The deep seated carbonation of the rocks, which is so well marked at almost all the other important gold-mining centres (*e.g.*, Kalgoorlie, Warrawoona, Meekatharra, Bullfinch and Ora Banda) is here almost absent, secondary carbonates being detected only in small quantities in a very few rocks.

The metallic minerals so far recorded are somewhat unusual in kind, and for an explanation of this one must turn to the entirely unusual occurrence of the gold, the sole object of the local mining activity. The gold at Westonia is for the most part found in dykes or veins of pegmatite or pegmatitic quartz, or impregnations immediately adjacent thereto, the term "pegmatitic quartz" being used for the quartz of a vein which, whilst in one place it may appear to consist of quartz only, can be traced without break into a quartz enclosing microcline in greater or less abundance, the whole vein being thus essentially a pegmatite. Under these circumstances it is not surprising that mining operations have disclosed the presence of such typical pegmatite minerals as molybdenite, wolfram, and xenotime, none of which have been recorded from any of the other centres mentioned in the previous paragraph.

In the following pages some details are given regarding the individual mineral species observed, which number more than forty. Only the briefest record is made of the purely rock-forming species, these being dealt with more fully by the Petrologist in Section D. The order followed in this section has been that of Danas System of Mineralogy.

NATIVE ELEMENTS.

Native Gold (Alloy of gold and silver).—The abundance of native gold at Westonia is the *raison d'être* of its existence as a mining town, in fact as a town at all. No compounds of gold are known in the district. The metal occurs in ragged grains in pegmatite veins, which in places are coarse mixtures of quartz and microcline, *e.g.* [1/1226], Weston's Reward G.M., in places pass into a typical granite, *e.g.*, [1/1163], Recovery G.M., and again in places possess the characters of ordinary quartz veins. Some of the latter may not be genetically connected with the pegmatites, but in many cases they have been traced into microcline-bearing quartzes. In addition to these minerals, pyrite, marcasite, galena, biotite, wolfram and molybdenite are the chief associated minerals of the unweathered zone, and kaolin, iron hydrates, miloschite, pyromorphite, wulfenite, and crocoite the chief secondary minerals. At the Jessie G.M., near Boodalin Soak, gold has been observed in a gabbro pegmatite, composed mainly of coarse green hornblende, with epidote. This gold is probably an infiltration from a near-by quartz stringer.

Only one specimen of native gold has been analysed. This was from a small vugh in the weathered pegmatite forming the main lode in the Edna May G.M. at a depth of 225 feet (68 metres). It contained 95.14 per cent. of gold, 4.86 per cent. of silver, and only minute traces of base metals.

In addition to the gold found in lodes, the metal is also found in a buried stream bed (deep lead) on the Edna May Central G.M. This consists of large and small quartz pebbles cemented by clay. Much of the gold is in thin and thick films on the surface of the pebbles or in minute cracks in the pebbles or in the cementing material, [1/1222]. This is plainly not alluvial gold in the true sense of the term, but secondary gold deposited by chemical action out of percolating gold-bearing solutions during or after the burial of the stream bed.

METALLIC SULPHIDES.

Molybdenite (sulphide of molybdenum).—Some very fine specimens of this mineral in pegmatitic quartz [1/1225] were obtained from a patch in the Edna May main lode at 260 feet (79 metres) in the Central Mine. The only associated mineral other than the quartz is a little pyrite. The mineral is in coarsely foliated masses up to two inches (5cm.) in diameter, and one-eighth inch (3mm.) thick. Odd masses are scattered through the quartz, but the chief aggregation is on a fracture plane, which is almost completely coated with it. A few small scales are also seen scattered over a foliation plane of the biotite gneiss close to some interbedded quartz stringers from the ore body at the 225ft. (68 metres) level of the Edna May G.M. [1/1224]. Mr. Blatchford further reports the presence of the same mineral in the Edna May Deeps G.M.; and Mr. Stokes has collected at the 560ft. level in this mine a sillimanite gneiss with interfoliated films of molybdenite.

The patches of this mineral are nowhere apparently of sufficient extent to be worth treating for the recovery of the mineral, even at the present very high price of £5 per unit of MoS_2 for 85 per cent. concentrates.

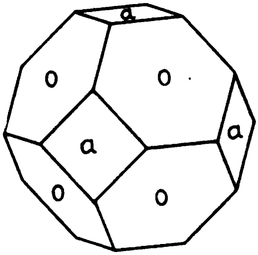
Galena (Sulphide of lead).—Galena is seen in only two specimens collected by Mr. Blatchford. One, [1/1225], is a grey quartz gold ore from the big bulge of the main lode at the north-east end of the 300ft. level in the Edna May G.M. Galena is quite abundant in this specimen in masses up to one inch (25mm.) in length with coarse cubical cleavage. No blende was associated with it. A similar specimen, [1/1262], was collected in No. 1 stope at the 225ft. level of the same mine.

Pyrrhotite (Sulphide of iron).—Pyrrhotite is far from common at Westonia. It was seen in a specimen of the Edna May biotite gneiss taken from a depth of 223 feet (68 metres) in Duff's Bore on the Edna May Deeps Mine. The powdered rock, on moistening with dilute hydrochloric acid, yielded a strong smell of sulphuretted hydrogen, and analysis showed the presence of 1.24 per cent. of pyrrhotite associated with 0.11 per cent. of pyrite. Sections of the rock show the pyrrhotite to be a secondary impregnation, deposited mainly in narrow fractures following the outlines of the original quartz grains, and to a slight extent spreading from these into the solid masses of adjacent minerals.

A few small grains were detected in a specimen [1/1223] of felspathic quartz, showing free gold, from the 225ft. level of the Edna May Mine, and in an ore with much galena from the 300ft. level of the same mine.

Pyrite (Bisulphide of iron).—Although pyrite is the most common sulphide at Westonia, it is not abundant in most mines, the unoxidised ores containing, as a rule, only small proportions of sulphides. An exception is the sulphide ore collected by Mr. Blatchford in the Hill End Mine [1/1263, 1/1264], which contains a large amount of massive and crystallised pyrite associated with quartz and some marcasite. The common form of pyrite crystal

Fig. 48.



Crystal of pyrites from sulphide gold ore, Hill End Gold Mine, Westonia.

in this ore is the combination of the octahedron and the cube, *vide* Fig. 48.

Small grains and strings of pyrite were detected in most of the country rock from below water level.

Marcasite (Bisulphide of iron).—Some specimens of sulphide ore from the Hill End G.M. contain an iron sulphide which rapidly oxidises to ferrous sulphate on exposure to the air, even within doors. This is doubtless marcasite. It occurs both alone in quartz, and in patches with normal pyrite, *see* [1/1264].

HALOGEN COMPOUNDS.

Salt, Halite (Chloride of sodium).—The underground waters of the district are strongly saline, and, by leaching with water, the presence of dry salt and epsomite derived from the water can be proved in most of the more porous weathered rocks at a little distance below the surface.

OXIDES AND HYDRATED OXIDES.

Quartz (Oxide of silicon).—Plentiful as a constituent of granites, gneisses, pegmatite veins and quartz veins. Both the latter are frequently payably auriferous. The quartz veins are in many cases only extremely siliceous phases of the pegmatites, since in some of them occasional microcline crystals are found, and with regard to others, mining operations have proved their continuity with undoubted microcline pegmatites.

Opal (Hydrated oxide of silicon).—At the 300ft. level of the Edna May Mine a little opal has been disclosed in the ultra-basic wall rock some distance from the lode. It is in irregular masses associated with quartz, serpentine, kaolin, pyrite, and a rich green earthy mineral, probably a variety of miloschite (*q.v.*). The opal is in part "liver-opal" [1/1269], brownish, and opaque from inclusions of kaolin, iron oxides, etc. In part it is green, of various shades, sometimes translucent, sometimes almost opaque [1/1268]. An analysis was made of some of the almost transparent,* deep sea-green mineral with the following results:—

Green Opal, Westonia.

Silica, SiO_2	92·19
Water, H_2O	7·46
Chromium oxide, Cr_2O_3	·14
Ferrous oxide, FeO	·18
Nickel oxide, NiO	*Nil*
Copper oxide, CuO	*Nil*
Magnesia, MgO	trace
Alumina, Al_2O_3	trace
	99·97
Specific gravity	2·05

---

* Print could be read easily through flakes 1 mm. in thickness.

Green opal is not uncommon throughout the world in association with altering peridotitic rocks, particularly serpentines, and in such situations four possible colouring agents may account for its tint, viz., FeO, NiO, CuO, and Cr_2O_3, of which the last is the most intense in its effect.

Hintze's * and Doelter's † tables show that iron oxides are present in practically all coloured opals. Leitmeier shows no nickel, copper, nor chromium in any of his 47 analyses tabulated in Doelter's Handbuch, but on p. 258 says:—

> The green colour of the so-called prase opal is produced by a small proportion of nickel (see p. 246).

And on p. 246:—

> An opal with a nickel content of 1 per cent. is described by M. H. Klaproth from Kosemitzer Mt. (Silesia), where it occurs in association with chrysoprase.

Hintze also, amongst his 94 analyses of opal, has none which shows either nickel, copper, or chromium; but he too, on page 1511, refers to Klaproth's 18th Century (1795) statement that one per cent. of nickel is present in a Silesian green opal.‡

The analysis of the Westonia opal is therefore of unusual interest as indicating for the first time the presence in this mineral of chromium oxide, which, from its known intense colouring power when present as a silicate in such minerals as beryl, fuchsite, and miloschite, must be the main cause of the green tint, varying from light to deep sea-green. The tenacity with which hydrous silica will retain small amounts of chromium oxide, even in the presence of strong acids, may be observed in analysing any chromiferous silicate, such as fuchsite. In analysing miloschite from Westonia the author found that Cr_2O_3, to the extent of 0.25 per cent. of the SiO_2, was the only impurity retained by the hydrous silica§ after several treatments with strong hydrochloric acid, followed by complete washing with water. The ignited silica was distinctly green in colour when wetted.

The original source of the chromium oxide in this chromiferous opal is the chromite of the basic rocks.

Rutile (Oxide of titanium).—Only three occurrences of rutile were noted. The most interesting was in the sillimanite gneiss from the Hill End G.M. where it is seen under the microscope in innumerable pale yellow needles embedded in bleached (chloritised) biotite. The original unbleached mica, which is deep brown in colour, is evidently highly titaniferous, like several brown biotites tabulated by Hintze and coming from Norway, Russia, Germany and the United States. These have been found to contain from 3.16 to 4.68 per cent. of combined titanic oxide. The conversion of such a titaniferous biotite into chlorite evidently leads to the titanium oxide crystallising out in the form of rutile needles. In some of the altered biotite flakes in the Hill End gneiss, the rutile needles are distributed quite irregularly, *vide* lower left-hand side of Fig. 49. In others the rutile needles form a perfect geometrical web (sagenite), due to twinning on (101), *vide* top right hand side of Fig. 49. A beautiful instance of the occurrence of reticulated rutile in an altered biotite is described under the heading "Biotite" on p. 237.

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* Hintze, Handbuch der Mineralogie, I. pp. 1535–8.

† Leitmeier in Doelter, Handbuch der Mineralchemie, II., pp. 242–6.

‡ On page 194 of the 1889 issue of the 5th Edition of J. D. Dana's System of Mineralogy the complete analyses of this nickeliferous opal, by Klaproth and Rammelsberg, are given. Klaproth found 1·00 per cent. NiO, Rammelsberg, 0·41 per cent.

§ Obtained by evaporating with hydrochloric acid the fusion with alkali carbonates.

Fig. 49.

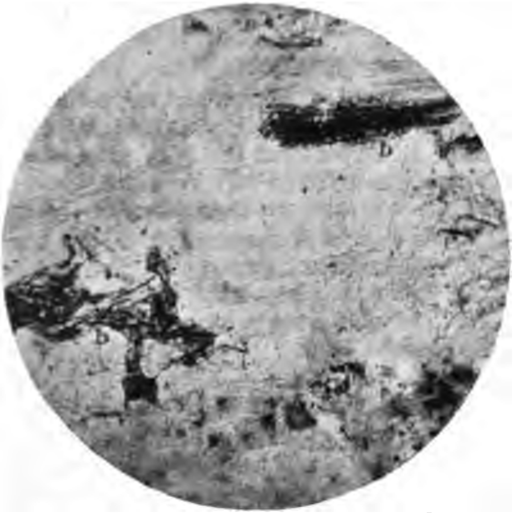

Photo: E. S. Simpson. Neg. 1599.

Secondary rutile in bleached biotite, Hill End Gold Mine, Westonia.

(× 45)

Granular rutile was observed embedded in the scaly miloschite from the Edna May Central G.M.

Ilmenite (Oxide of iron and titanium).

Magnetite (Oxide of iron).—These two minerals occur in microscopic grains as minor constituents of the various greenstones. In a few instances the ilmenite was observed to be wholly or partly altered into amorphous leucoxene (doelterite?).

Chromite (Chromite of iron).—This was proved to be present in minute black grains to the extent of 0.24 per cent. in the serpentinised peridotite from Duff's Bore, Edna May Deeps Lease.

Chromite is the original source of the chromium of three secondary minerals found in the zone of weathering, viz., crocoite, green opal, and miloschite.

Limonite and other iron hydrates are abundant in the weathered rocks and soils.

Asbolite (Hydrated oxide of manganese and cobalt).—A thin black coating on a fracture face of a pegmatite from the Edna May Central G.M. was proved to be asbolite moderately rich in cobalt.

CARBONATES.

Dolomite (Carbonate of calcium and magnesium).—A carbonate which, from its chemical behaviour, is probably dolomite, occurs to a small extent (under one per cent.) in scattered granules in a specimen of biotite gneiss from Duff's Bore at 223 feet (67 metres), the analysis of which is given on page 293.

Magnesite (Carbonate of magnesium).—From the Edna May Deeps Lease a large nodule of pure white magnesite has been collected. No details are available as to its occurrence. Mr. Blatchford observed concretions of impure magnesite in the surface soil in the vicinity of Boodalin Soak.

ANHYDROUS SILICATES.

Orthoclase and Microcline (Silicates of aluminium and potassium).—Orthoclase has not been definitely recognised at Westonia, but as no typically crossed twinned microcline is visible in the Edna May gneiss, the potash not present as biotite in that rock is thought to exist as orthoclase.

Microcline has been recognised by the Petrologist in the main granite batholith, in a granite dyke one mile north-west of Westonia townsite, and in the gneiss of the Battler Group. In variable amounts it is a constant constituent of the pegmatite veins, including the auriferous ones, such as the Edna May "main lode," in which gold is sometimes found embedded in felspar, as also in the granite dyke of the Recovery Mine. From a reputedly auriferous pegmatite vein on the Violet May Lease, 2878, west of Boodalin Soak, Mr. Blatchford collected a specimen [1/1261] of very coarsely crystallised white microcline associated with quartz, the masses of felspar being several inches square.

Owing to the ease with which microcline passes into kaolin in the presence of weathering pyrite, the microcline-bearing pegmatites pass upwards into vughy quartz veins, in which the hollows left by the weathering out of the felspar become repositories of various secondary minerals such as pyromorphite.

Oligoclase (Silicate of aluminium, sodium and calcium).—A felspar identical with oligoclase or closely related to it is common in the granite and gneiss.

Labradorite (Silicate of aluminium, sodium and calcium).—Common in the more felspathic amphibole rocks.

Pyroxene, Augite (Silicate of calcium, magnesium, iron and aluminium).—This is rare as a rock-forming mineral in the Westonia district, being recorded by the Petrologist in only three rocks. The rarity is to be ascribed to the wide-spread uralitisation that has affected the greenstones of the area.

Garnet, Almandine? (Silicate of aluminium and iron).—A very dark red garnet of undetermined species occurs in a garnet-sillimanite schist near the Battler G.M. The crystals, which are trapezohedra (211), with occasional small faces of the rhombic dodecahedron (110), reach up to ⅜ inch (10 mm.) in diameter. They resemble Danas Figs. 1 and 2 (System, VII. Edit., p. 438). The Petrologist has noted the presence of small red garnet crystals in a fine-grained white granite from 250 feet in No. 3 Bore, Edna May Lease.

Chrysolite, Olivine (Silicate of magnesium and iron)—This mineral is abundant in a partly serpentinised actinolite-peridotite passed through in Duff's Bore, Edna May Deeps Lease, at a depth of about 460 feet (140 metres), and again at 570 feet (173 metres). Whilst some of the mineral has been converted into serpentine, a considerable proportion is seen under the microscope to be still quite fresh, colourless, and transparent, with typical high birefringence, though much cracked.

Zircon (Silicate of zirconium).—Minute colourless prisms of zircon were observed in sections of the biotite gneiss of the Edna May Group, in sections of the sillimanite gneiss of the Hill End Mine, and in concentrates from a microcline pegmatite.

Andalusite (Silicate of aluminium).—A single specimen of this has been observed. It was collected on the Edna May Consolidated Lease, 2617. It is in a mass of pale pink, slightly divergent prisms, with prismatic cleavage. Its density is 3.10; hardness, 7; and pleochroism strong, deep pink to colourless. A qualitative test showed the presence of large proportions of silica and alumina (60 per cent.), with traces of iron, manganese, and magnesia. Lime and boric acid were shown to be absent. The only associated mineral is muscovite.

Sillimanite (Silicate of aluminium).—This mineral is abundant in a contact rock, a garnet-sillimanite gneiss or schist, about one mile south of the Battler G.M. The rock consists largely of isolated fibres, and thick bundles of fibres, of almost colourless sillimanite, with numerous flakes of brown biotite, large crystals of garnet and granular quartz and microcline. The rock is probably an altered hornblende granite or granodiorite.

A second rock [1/1156] from the Hill End Mine is a typical pale grey, dense and tough sillimanite gneiss, composed of quartz, felspar, and biotite, with abundant colourless needles of sillimanite, either isolated or aggregated in thick bunches and sheaves, which to the unaided eye appear in a thin section to be in parallel lenses following the lines of schistosity. See Figs. 50 and 51. The needles

Fig. 50.

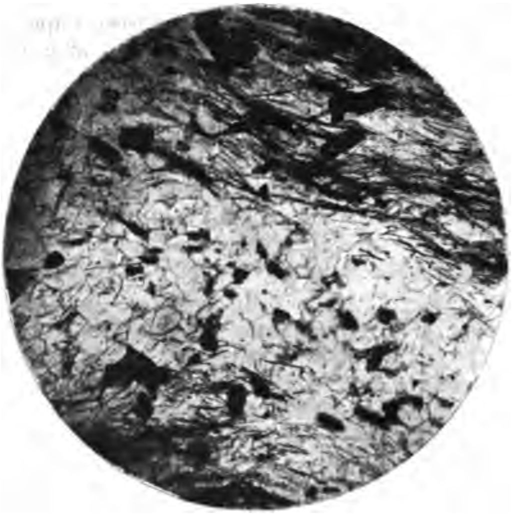

Photo: E. S. Simpson. Neg. 1598.

Sillimanite in gneiss, Hill End Gold Mine, Westonia.

(× 45)

are colourless, often straight, but frequently curved. The crystals are so small in diameter and so thoroughly embedded in quartz or felspar that their optical properties were only determinable in the thinnest portion of the sections (0.02mm). Their mean refractive index was found to be distinctly higher than quartz, double refraction high, not markedly different from that of tremolite, but the extinction is invariably straight, **Z** being parallel to the elongation. Rectangular cross fractures are not infrequent, and the needles pass uninterruptedly right through several adjacent quartz grains. The sillimanite is unevenly distributed and in any microscopic field is most abundant in those portions of the section which contain least felspar and biotite, both of which minerals are only very rarely penetrated by needles of the sillimanite.

In both rocks the average diameter of the needles is only about 1-200th mm (1-2,500th inch), the largest reaching to 1-30th mm (1-750th inch). They are invisible in hand specimens of the Hill End rock, but parallel bundles of fibres are easily seen with the unaided eye in the garnet-sillimanite gneiss.

Recently Mr. H. G. Stokes has collected a typical coarse sillimanite gneiss at the 560ft. level of the Edna May Deeps Mine, where it forms a band in the Edna May biotite gneiss. In this rock the crystals, which are of a pale brown tint, not infrequently reach 2mm., and at times 5mm., in diameter. They are either simple unit prisms, or combinations of (100), (110) and (001). (Des Cloiseaux' orientation.)

The only other locality in the State at which I have observed sillimanite is on the shore at Ellensbrook, between Capes Naturaliste and Leeuwin, where it occurs in foliation planes of a garnetiferous gneiss.

The exact details of the genesis of sillimanite in a granite gneiss have not been worked out, but, theoretically, by interaction between microcline and an aluminous hornblende (both of which are known to be primary constituents of the less altered Edna May gneiss) it should be possible to develop at high temperatures a mixture of biotite, sillimanite, and garnet, or other lime silicate, with the aid of but little or no carbonic acid, which last is known not to have played an important part in the metasomatism of the Westonia rocks.

Fig. 51.

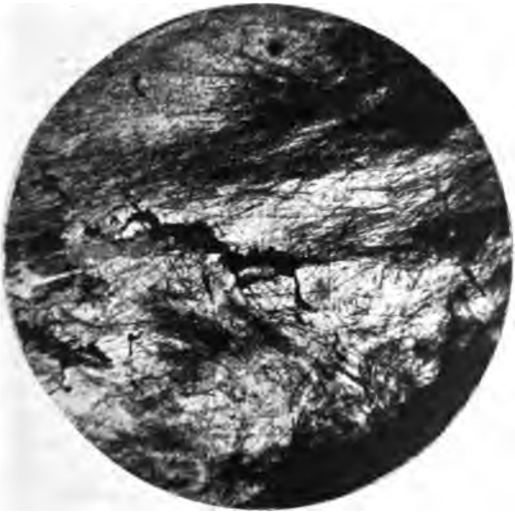

Photo: E. S. Simpson. Neg. 1597.

Sillimanite in gneiss, Hill End Gold Mine, Westonia.

(× 45)

Thus:

$$\underset{\text{Hornblende}}{4(\mathrm{Mg, Fe})_2\mathrm{CaSi_4O_{12}}\cdot 6(\mathrm{Mg, Fe})_2(\mathrm{Al,Fe})_4\mathrm{Si_2O_{12}}} + \underset{\text{Microcline}}{8\mathrm{KAlSi_3O_8}} + \underset{\text{Water}}{4\mathrm{H_2O}} \quad \text{Yield}$$

$$\underset{\text{Sillimanite}}{4\mathrm{Al_2SiO_5}} + \underset{\text{Biotite}}{8(\mathrm{Al,Fe})_2(\mathrm{Mg,Fe})_2\mathrm{KHSi_3O_{12}}} + \underset{\text{Garnet}}{4\mathrm{Ca(Mg,Fe)_2Al_2Si_3O_{12}}} + \underset{\text{Quartz}}{12\mathrm{SiO_2}}$$

The simultaneous development of secondary quartz and sillimanite will explain the otherwise inexplicable penetration of several adjacent quartz grains by minute straight needles of sillimanite, and also the paucity of felspar in the immediate vicinity.

Titanite (Sphene) (Titano-silicate of calcium).—Large grains and occasional typical wedge-shaped crystals of this mineral, of a honey-yellow colour, are present in abundance in the biotite gneiss of the Edna May group. Small granules are recorded by the Petrologist in very many of the greenstones.

HYDROUS SILICATES.

Amphibole—Actinolite and Hornblende (Hydrous silicates of calcium, magnesium, and iron, the latter also with aluminium).—Green amphiboles, usually secondary, and referable to these two species, are abundant in the amphibolites and epidiorites, and occasionally replace the biotite of the gneiss of the Edna May group. An auriferous gabbro pegmatite, from the Jessie G.M., is composed mainly of large (5cm.) greenish black hornblende crystals.

Zoisite (Hydrous silicate of aluminium and calcium).—Occurs in minute microscopic granules in many of the hornblende rocks.

Epidote (Hydrous silicate of aluminium, iron and calcium).—Coarse masses of prismatic epidote of a pale honey yellow colour are seen filling the interstices between the large hornblende crystals of a gabbro pegmatite from the Jessie Gold Mine, near Boodalin Soak. Microscopic granules of epidote are not uncommon in some of the altered hornblende rocks.

Muscovite (Hydrous silicate of aluminium and potassium).—This mineral has not been observed in the district except in a pegmatite on G.M.L. 2617, and on rare occasions as microscopic scales replacing felspar. This paucity of muscovite is in marked contrast to the conditions prevailing in many others of the important gold-mining centres, where secondary sericite is abundantly developed in or adjacent to auriferous lodes.

Biotite (Hydrous silicate of aluminium, iron, magnesium, and potassium).—Brownish black biotite is abundant at Westonia, chiefly as a prominent constituent of the Edna May gneiss. Not uncommonly it is found in large flakes in the auriferous pegmatite, *e.g.*, at 225ft. in the Edna May Mine [1/1260]. Fine, scaly biotite is also present in the auriferous pegmatite of Weston's Reward G.M. As a secondary mineral it is not rare in altered types of both hornblendic and peridotitic greenstones. The colour throughout is a typical red brown, with optic axial angle apparently nil. In the sillimanite gneiss of the Hill End Mine many of the brown biotite flakes are completely bleached, and such flakes contain a reticulated collection of rutile needles. The original mineral must, therefore, be highly titaniferous. In specimens of lodestuff (coarse microdine pegmatite) from 550ft. in the Edna May Deeps G.M., all the stages of alteration can be seen, from coarsely crystallised red-brown biotite devoid of rutile through partly bleached biotite carrying many rutile needles in the altered portions to a greenish grey, coarsely foliated chlorite enclosing a dense network of yellow rutile crystals.

Chlorite (Hydrous silicate of iron, magnesium, and aluminium).—Scales of chlorite are common in the greenstones, but no completely chloritised rocks (propylites or chlorite schists) are known. For pseudomorphs after biotite, *vide* supra.

Serpentine (Hydrous silicate of magnesium).—This was observed in a partly serpentinised olivine rock in Duff's bore on the Edna May Deeps Mine, where it was for the most part pseudomorphous after olivine. It is also seen in the workings of the Edna May Mine.

Chrysocolla (Hydrous silicate of copper).—This is the only copper-bearing mineral detected at Westonia. A few small bluish green grains are seen in the wulfenite-bearing quartz from the Edna May Deeps Lease. These are not readily attacked by nitric acid but break up with hydrofluoric acid, giving a solution which reacts for copper. The grains appear to be a mixture of chrysocolla and silicified kaolin.

Kaolinite and Halloysite (Hydrated silicates of aluminium).—These minerals are common as finely divided constituents of the clays resulting from the weathering of the granites, pegmatites, and greenstones. In their ordinary form they call for no comment.

Miloschite, the chromiferous variety of kaolinite, is a sufficiently rare and little known mineral to be worthy of detailed notice. It occurs in several mines of the Edna May group at Westonia either in fine or coarse scales, up to five-eighths inch (15mm.) in diameter, which are probably pseudomorphs after fuchsite (chromiferous muscovite), or in earthy masses which may be alteration products of other aluminous silicates. It is distinguishable in appearance from fuchsite by its greenish-blue to bluish-green colour and by the finely wrinkled surface and pearly lustre of the scaly mineral. Furthermore, it is softer and more friable than the mica. Chemically it is distinguished by the absence of potash and by the large yield of water on ignition.

Tabulated Comparison of Fuchsite and Miloschite.

	Fuchsite.	Miloschite.
Colour.	Emerald green.	Greenish blue or bluish green.
Lustre of flakes	Vitreous	Pearly
Density...	2·84	2·58
Hardness	2 to 3	1½ to 2
Elasticity	high	very small
Water content, %	4½	14
Potash content, %	11	*nil*

Miloschite was first described in 1838,* on material from Serbia. The original imperfect descriptions were augmented only in 1894 by Losanitsch,† who considered that he had found two substances present in the Serbian material, a bluish crystalline mineral, miloschite, the chromiferous equivalent of kaolinite, and a green amorphous mineral, alexandrolite, possibly the chromiferous equivalent of halloysite. Losanitsch's analysis of the Serbian miloschite agrees closely with the theoretical composition of a chromiferous kaolinite, viz., with $(Al,Cr)_2O_3.2SiO_2.2H_2O$, but an earlier (1839), probably unreliable, analysis by Kersten shows much more water, whilst the relative amounts of silica and alumina are transposed. Several "chrome ochres" (including selwynite), which have been described from time to time, are undoubtedly impure miloschite (or alexandrolite, if this is distinct from miloschite), mixed with fuchsite and sometimes talc, and resulting from the partial or complete decomposition of fuchsite rocks.

The latest and most complete description of miloschite is that of the mineral from Ely, Nevada, by E. T. Wherry and G. V. Brown.‡ Their "formal description" requires consideration in two respects. They describe the mineral as monoclinic, biaxial, with axial angle about 90°, but they give the refractive indices as α and β, 1.552; and γ, 1.559 (all $\pm$ 0.003). It is evident that if α and β are really equal, the mineral is uniaxial and the optic axial angle is nil, but with a possible error of $\pm$ 0.003, α may be 1.551 and β 1.553, which would give an optic axial angle somewhat less than 90°. They do not give the sign of the birefringence, but if α almost equals β, the sign is positive, though all authorities (Dana, Miers, Zirkel, etc.) are agreed that kaolinite is negative. The optical orientation of the Nevada mineral is stated to be indeterminate.

The density given by them is 2.1 +, which cannot be reconciled with that of normal kaolinite, viz., 2.57 — 2.63, since a slight replacement of aluminium by chromium should only slightly alter the density of kaolinite, and that in an upward direction, chromium having a higher atomic weight than aluminium.

The Nevada mineral, like that previously described from Serbia, was moderately impure, as the analysis in the table below shows. Thus, in addition to the essential alumina, chromium oxide, silica and water, it contained nearly one per cent. of ferric oxide, which may, however, be an isomorphous replacement of alumina, and therefore an intrinsic constituent of the mineral. Further, it contained § 0.37 per cent. lime, 0.11 per cent. magnesia, and 0.28 per cent. potash, which can only be present as mineral inclusions such as mica, etc. If the potash represent unaltered fuchsite, then the analysed material contained not less than 2.5 per cent. of this mineral. In addition, the Nevada miloschite contained some foreign lime-bearing and magnesium-bearing silicates, such as talc, etc.

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* J. pr. Chem., 1838, XV., 327.
† Chem. News, 1894, LXIX., 243.
‡ Amer. Mineralogist, 1916, I. 63.
§ Mean values of the two analyses.

Special interest therefore attaches to the Westonia mineral, which is proved by analysis to be so much purer than anything previously described. To obtain material for analysis, a specimen [1·1272] from the north crosscut at the 75ft. (23 metres) level of the Edna May Central G.M. was chosen. This was strongly foliated and tender to handle, and consisted apparently wholly of pale eau-de-nil coloured scales, in one part of the specimen fairly coarse (2 to 3 mm.), in another distinctly smaller, the whole specimen having the structure of a mica schist. Some of the coarser portion was broken off and rubbed lightly for some time in a porcelain mortar and then divided, by sifting, into two portions, viz., Lot A, the fine flakes which passed a 60-mesh sieve, and Lot B, the larger flakes, which refused to pass that sieve. Both lots were well washed with distilled water to remove common salt and magnesium sulphate derived from the very saline mine waters. The washed mineral was then thoroughly air-dried and disintegrated before analysis. The analytical results are given in the accompanying table:—

Analyses of Miloschite.

——	Rudniak, Serbia.	Ely, Nevada.	Westonia, W.A.			
			Lot A.		Lot B.	
	%	%	%	mols.	%	mols.
Water at 100 deg. ..	..	3·54	0·98	..	0·80	..
Rutile	..	..	0·57	..	0·32	..

Analysis of Dry Mineral free from Rutile.

	Rudniak, Serbia. %	Ely, Nevada. %	Westonia Lot A. %	Lot A. mols.	Westonia Lot B. %	Lot B. mols.
Water, H_2O	13·76	13·76	13·89	771	14·03	778
Silica, SiO_2	46·37	45·06	46·84	776	46·39	769
Alumina, Al_2O_3 ..	30·18	35·66	37·95	380	38·88	387
Chromium oxide, Cr_2O_3	9·75	3·99	1·22		1·02	
Iron oxide, Fe_2O_3 ..	·91	·89	·06		·05	
Lime, CaO	..	·38	*Nil*	..	*Nil*	..
Magnesia, MgO ..	trace	·11	·36	9	·19	4·6
Potash, K_2O	trace	·29	·07	..	·05	..
Soda, Na_2O	..	..	·04	..	·02	..
Totals	100·97	100·14	100·43	..	100·63	..
Density ..	?	2·1+	2·59	..	2·58	..

In this table are given, for comparison, Losanitsch's analysis of Serbian miloschite, and the figures for the Nevada mineral recalculated after deducting only the water lost at 105°. Wherry and Brown* recalculate their mean figures after deducting also all lime, magnesia, and potash. This, however, must lead to incorrect and misleading results, as these constituents cannot possibly occur as an admixture of the free oxides, nor is any natural compound known of any two or of the three of them. It is practically certain that they are present as silicates or alumino-silicates, and if the bases are deducted from the totals, the corresponding amounts of silica and alumina should also be deducted. These not being ascertainable, I have left the lime, magnesia, and potash in the final results.

In the case of the Westonia miloschite the analyses reveal that there is no appreciable difference between the coarser flakes which resisted the partial disintegration in the mortar and the finer flakes which readily separated and passed through the fine sieve. Both agree very closely with the theoretical composition required by the formula: $(Al,Cr)_2O_3.2SiO_2.2H_2O$. In recalculating the original figures of the analysis, the small amount of water lost at 100° was rejected, as it was plainly not an essential constituent. All the titanium oxide also was rejected, as complete proof of its existence as finely granular rutile was readily obtained. Both analyses show a small content of magnesia, a constituent foreign to the theoretical composition. It is highly probable that this exists as interleaved scales of talc. If the magnesia be deducted from the analytical results, together with the proportions of silica and water necessary to form talc, the remaining constituents are present in the following proportions:—

	Lot A.	Lot B.	Theory.
$(Al,Cr,Fe)_2O_3$ ..	0.994	1.004	1.0
SiO_2	1.998	1.980	2.0
H_2O	2.009	2.015	2.0

It will be observed that the proportion of chromium present in the mineral analysed was considerably less than in the minerals from Serbia and Nevada. In a second specimen [1/1274] from the same spot, viz., the 75ft. level of the Edna May Central Mine, some much larger flakes of miloschite are present (up to five-eighths inch) which are considerably deeper in colour, approaching a turquoise blue. This depth of colour was found to be partly due to a slightly higher percentage of chromium, viz., 1.50 per cent. of Cr_2O_3, and partly to the state of aggregation, the mineral being in dense cleavable masses, practically devoid of air films between the cleavages. The deeper green portion of a variously shaded green earthy clay, carrying much free gold, and collected also in the Central Mine, was found to contain 7.4 per cent. Cr_2O_3.

The Westonia miloschite is very resistant to hot concentrated (10E) hydrochloric acid, but is completely and rapidly dissolved by warm concentrated (20E) hydrofluoric acid. Hot fuming sulfuric acid dissolves out the bases, leaving scales of silicic acid of the same size and shape as the original mineral. Fusion in the air with alkali carbonates completely decomposes it, forming yellow alkali chromate soluble in water. Heating to a low red-heat drives off most of the combined water, and causes a great part of the colour to disappear owing to the formation of air films in the mass. The mineral does not appreciably exfoliate during heating, and is infusible before the blow-pipe.

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* Loc. cit.

The apparent outward form of the Westonia miloschite is not necessarily its intrinsic form, but may be that of the fuchsite (chrome mica), after which it is pseudomorphous. The mineral throughout possesses a perfect basal cleavage, but many of the larger flakes are seen under the microscope to be complex, having a grey dusty interior, due to the aggregation of minute scales within the larger plate. This appearance is characteristic of much kaolinite. On the other hand, a large proportion of the smallest scales of miloschite are homogeneous and possess optical properties related to their form. They are biaxial, with such a small difference in refringence along the two axes of elasticity lying approximately parallel to the surface of the flake, that lamellæ lying at right angles to the axis of the microscope appear uniaxial with parallel polarised light, but give an indistinct biaxial figure with convergent light. The third axis is roughly normal to the surface of the flake, and the refringence along this axis is shown by a quartz wedge to be distinctly less than along either of the other axes, first order interference tints being obtained with the finely divided mineral. Attempts to determine the refractive indices by means of a Herbert Smith refractometer failed owing to the wrinkled surface of the flakes and their frequently composite character. The optical properties may be summarised thus:—

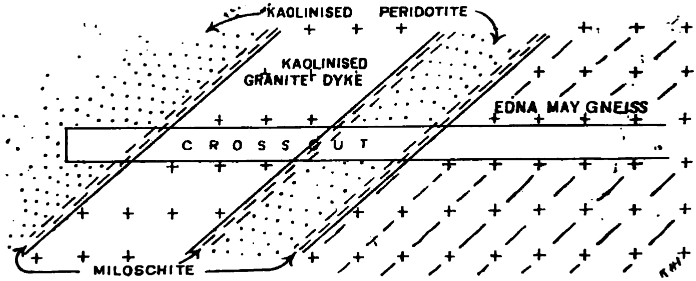
$\alpha < \beta = \gamma\,(-)$: optically negative: α approximately normal to the surface of the flakes, *i.e.*, approximately parallel to the vertical crystallographic axis. Mean refractive index (by immersion) slightly greater than 1.54. Pleochroism inappreciable. Opaque, except under the microscope in very thin scales. Colour, very pale greenish blue, through turquoise blue to deep bluish green, the depth of colour increasing with rise in the percentage of chromium present. Lustre of scales, satiny or nacreous; of earthy mineral, dull earthy.

The habit of the mineral varies from earthy through fine scaly to coarse lamellar, the surface usually minutely wrinkled. Perfect cleavage in the scales. Hardness, 1.5 to 2.0, difficult to estimate owing to the fragility of the aggregates. Density, 1.58 to 1.59.

The mineral has been recorded from the Edna May Central, the Edna May Golden Point, and the Edna May Consolidated mines.

Its occurrence in the first-named mine is illustrated in Fig. 52. In this mine, in the north crosscut at the 75ft. level, all the rocks are almost completely kaolinised. In the peridotite, along its junction with the Edna May gneiss and with a granite dyke, thin sheets of what is practically a miloschite schist are found. This yielded the material analysed. In addition it is found as a massive earthy clay, extremely fine-grained and slightly tinted a greenish blue, enclosing in places nests of thick and broad lamellae of a rich greenish blue tint. In one part of the weathered greenstone in this mine, sporadic lumps of deep green earthy miloschite are found enclosing much "paint" gold. This close association of secondary gold with miloschite shows the necessity of studying in detail the origin and properties of this mineral if the question of secondary enrichment in this area is to be fully understood.

Fig. 52.



Vertical section showing occurrence of miloschite in north crosscut, 75ft. level, Edna May Central G.M.

On the Edna May Consolidated Mine masses of earthy miloschite are found of a fairly bright bluish green colour. [1/1273.]

From its situation and structure it is inferred that the miloschite at Westonia is largely a pseudomorph after fuchsite, a theory which would be definitely confirmed by finding the latter mineral in the corresponding situations below the zone of weathering. In view of the known resistance to ordinary weathering of all forms of muscovite, including fuchsite,* the active agent in the transformation must be sought in the sulphuric acid produced by the weathering of pyritic lodes. The action would be:—

$$\underset{\text{Fuchsite}}{2H_2O.K_2O.3(Al, Cr)_2O_3\cdot 6SiO_2} + \underset{\substack{\text{Sulphuric}\\\text{acid}}}{H_2SO_4} + \underset{\text{Water}}{3H_2O} \text{ yield}$$

$$3\left\{\underset{\text{Miloschite}}{(Al,Cr)_2O_3\cdot 2SiO_2\cdot 2H_2O}\right\} + \underset{\substack{\text{Potassium}\\\text{sulphate}}}{K_2SO_4}$$

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* In the Toodyay district, for instance, beautifully fresh fuchsite is found exposed at the surface.

If the ratio of Al to Cr be 47 to 1, then 801.6 grammes of fuchsite of density 2.80 have yielded 779.5 grammes of miloschite of density 2.58, a volume increase of 5.5 per cent., which completely explains the persistent wrinkling of the larger scales.

Chloropal (**Nontronite**) (Hydrous silicate of iron).—This mineral is plentiful in a specimen [1/1] of wall rock (amphibolite) from the side of Weston's lode in Weston's Reward Mine, near Kundalin Soak. It completely fills a series of small (⅛in. to ½in.) anastomosing veins in the shattered rock, and, in addition, it occurs as a partial replacement of coarse crystals of amphibole. It is massive, of the consistency of soap, greenish yellow to yellowish green in colour, or at times brownish from the presence of a small amount of ferric hydrate. It is for the most part very soft (H,1), but in places is somewhat harder, probably from the presence of a little secondary silica. Though apparently amorphous and opaque to the naked eye, under the microscope it is found to consist of masses of minute transparent scales with ragged outlines and high birefringence.* Long narrow fragments, apparently scales on edge, give a straight extinction. It is readily decomposed by strong hydrochloric acid, granular silicic acid remaining.

The genesis of chloropal does not seem to have been dealt with to any extent by any of the standard authors, and may well, therefore, be considered in the light of the known Western Australian occurrences. Lacroix says,† in referring to the few known French occurrences:—

> It results from the decomposition of different rocks and particularly of granites. One finds it—
> (1.) In metalliferous deposits (manganese, lead);
> (2.) In fissures in granitic rocks;
> (3.) In sedimentary rocks.

In all cases it is found in this State under the following conditions:—

(1) As a vein filling, rarely as a replacement.

(2) In rocks containing a very ferruginous amphibole or chlorite, and close to metalliferous veins.

(3) In the zone of incipient weathering; never at the surface nor very close to it, the closest being 40 feet at Westonia.

In some cases chloropal is found near jasper bars, *e.g.*, at Ennuin, Meekatharra, Sandstone, and Southern Cross.

From information kindly supplied by Mr. E. de C. Clarke, the details of the occurrences at Meekatharra and Black Range are as follows:—

Queen of the Hill Gold Mine, Meekatharra. The mineral forms, with coarsely granular quartz, the filling of numerous small joints in a greenstone schist (sheared dolerite) at a point separated from the auriferous jasper by a few feet of non-auriferous jasper. at a depth of about 225 feet (68 metres), below the surface, the plane of separation of the oxidised and sulphide (pyritic) ore being seen in the adjacent stope. There is no record of chloropal at higher or lower levels in this mine.

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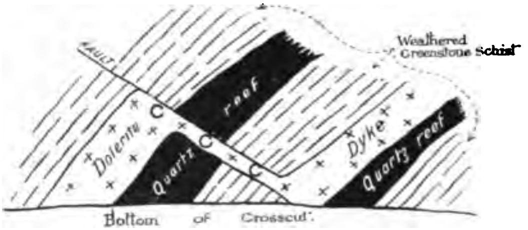
* The birefringence of nontronite is 0·025 according to Wherry & Brown, *vide* E. T. Wherry & G. V. Brown: "An American Occurrence of Miloschite." Amer. Mineralogist, I., 66.

† Minéralogie de la France, I., 490.

Oroya Black Range Gold Mine, Sandstone. In this mine a narrow unmetamorphosed dolerite dyke follows along the hanging wall of the auriferous quartz reef, both being surrounded by ancient greenstone schists. In places, at depths of 200 to 250 feet, the kaolinised dyke cuts across the reef, and where this occurs joints in the weathered dyke rock are found filled with chloropal. (See Fig. 53.) The nearest jasper bar runs at right angles to the reef, about 30 chains (600 metres) to the south.

Fig. 53.



Occurrence of chloropal, Sandstone.
(In joints at C, C, C.)

Mr. Blatchford informs me that in the Weston's Reward Mine the sulphide level is at about 60 feet, the chloropal occurring at 40 feet in the rock forming the wall of the reef.

Finally, regarding the origin and alterations of chloropal, we note that at Westonia it is in part pseudomorphous after a black. highly ferruginous amphibole, and shows a distinct tendency to alter into ferric hydrate (goethite, etc.); the mineral from a depth of 40 feet (*i.e.,* about 20 feet above sulphide level) being distinctly brownish in places exhibiting surface films and microscopic inclusions of red-brown ferric hydrate.

From the evidence to hand we infer that chloropal is never a primary mineral and that it is unstable on free exposure to the weather. From its general occurrence in veins we may conclude it is a precipitate from aqueous solution or colloidal suspension. I am inclined to ascribe its origin to the action of sulphuric acid solutions (from oxidising pyrites) on ferruginous silicates, with the production first of ferrous and ferric sulphate and colloidal silicic acid and the subsequent precipitation in the solution, by hydrolysis in the presence of the same or other minerals capable of neutralising the acid set free, or of oxidising ferrous sulphate, which would have the same effect. The reactions may be shown thus:—

(1) $$\underset{\text{Pyrites.}}{FeS_2} + \underset{\text{Oxygen.}}{7O} + \underset{\text{Water.}}{H_2O} \longrightarrow \underset{\text{Ferrous Sulphate.}}{FeSO_4} + \underset{\text{Sulphuric acid.}}{H_2SO_4}$$

(2) $$\underset{\text{Ferric Molecule of hornblende.}}{Na_2Fe_2Si_4O_{12}} + \underset{\text{Sulphuric acid.}}{4H_2SO_4} \longrightarrow \underset{\text{Ferric Sulphate.}}{Fe_2(SO_4)_3} + \underset{\text{Metasilicic acid.}}{4H_2SiO_3} + \underset{\text{Sodium Sulphate}}{Na_2SO_4}$$

(3) $$\underset{\text{Ferrous Molecule of Hornblende.}}{CaFe_2Si_4O_{12}} + \underset{\text{Sulphuric acid.}}{4H_2SO_4} \longrightarrow \underset{\text{Ferrous Sulphate.}}{3FeSO_4} + \underset{\text{Metasilicic acid.}}{4H_2SiO_3} + \underset{\text{Calcium Sulphate.}}{CaSO_4}$$

(4) $$\underset{\text{Ferric Sulphate.}}{Fe_2(SO_4)_3} + \underset{\text{Silicic acid.}}{3H_2SiO_3} + \underset{\text{Water.}}{5H_2O} \longrightarrow \underset{\text{Chloropal.}}{Fe_2O_3 \cdot 3SiO_2 \cdot 5H_2O} + \underset{\text{Sulphuric acid.}}{3H_2SO_4}$$

(5) $$\underset{\text{Ferrous Sulphate.}}{2FeSO_4} + \underset{\text{Sulphuric acid.}}{H_2SO_4} + \underset{\text{Oxygen.}}{O} \longrightarrow \underset{\text{Ferric Sulphate.}}{Fe_2(SO_4)_3} + \underset{\text{Water.}}{H_2O}$$

The instability of chloropal near the surface may be simply a case of dissociation, thus:—

$$\underset{\text{Chloropal}}{Fe_2O_3 \cdot 3SiO_2 \cdot 5H_2O} \longrightarrow \underset{\text{Goethite}}{Fe_2O_3 \cdot H_2O} + \underset{\text{Metasilicic acid.}}{3H_2SiO_3} + \underset{\text{Water.}}{H_2O}$$

or may be due to interaction with aluminium hydrate carried in solution and colloidal suspension in circulating waters, forming the more stable mineral halloysite, thus:—

$$\underset{\text{Chloropal.}}{2\,(Fe_2O_3 \cdot 3SiO_2 \cdot 5H_2O)} + \underset{\text{Al. hydrate.}}{3\,(Al_2O_3 \cdot 3H_2O)} \longrightarrow$$

$$\underset{\text{Halloysite.}}{3\,(Al_2O_3 \cdot 2SiO_2 \cdot 3H_2O)} + \underset{\text{Goethite.}}{2\,(Fe_2O_3 \cdot H_2O)} + \underset{\text{Water.}}{8H_2O}$$

PHOSPHATES.

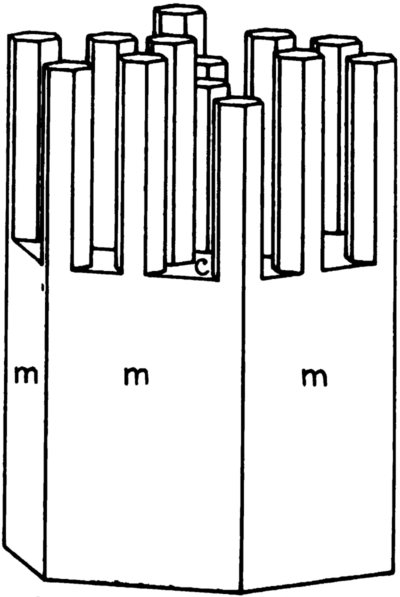
Xenotime. (Phosphate of yttrium, erbium, etc.).—Several small crystals of this very rare species were obtained by concentrating a microcline pegmatite from this district. The crystals are from 0.04 to 0.10 mm. (1/600 to 1/250 inch) in diameter. They sink in methylene iodide of density 3.3, are transparent or translucent, rarely opaque, mostly pale honey yellow in colour, but sometimes brownish. Their form is that typical of xenotime, viz., the low unit bipyramid of the tetragonal system. As there was just a possibility that this mineral might be zircon, it was tested for phosphoric acid. About two milligrams of the concentrates which had sunk in 3.3 methylene iodide and were composed mainly of ilmenite and the supposed xenotime, were warmed with dilute nitric acid for some time to remove any apatite that might be present. After washing and drying, the residue was fused with fusion mixture, the aqueous extract evaporated to dryness with nitric acid and then redissolved in dilute nitric acid. This solution gave a strong reaction for phosphate ion, confirming the identity of the xenotime.

Apatite (Fluophosphate of calcium).—A universal minor constituent of the granite gneisses and greenstones in microscopic colourless prisms. A "schliere" from a dyke at the 35-mile post on the York-Coolgardie road, nine miles south-east of Westonia, contained dull green hexagonal prisms of apatite up to 10 x 2 x 2 mm., associated with quartz, felspar, and hornblende. The crystals had a density of 3.2, and were readily soluble in dilute nitric acid, the solution giving a strong reaction for phosphate ion.

Pyromorphite (Chlorophosphate of lead).—This mineral is abundant in a specimen of cellular quartz (leached pegmatite), carrying much coarse free gold from the 225 feet level of the Edna May Mine. It is associated with a little crocoite.

The pyromorphite is in crystalline crusts and isolated crystals adherent to the exposed surfaces of quartz. The crystals are all hexagonal prisms with basal planes, and vary from 0.1 to 1.0 mm. in diameter. In the larger crystals the basal planes farthest from the supporting quartz are often covered with an outgrowth of a number of much smaller prisms in parallel position with the main crystal, as shown in Fig. 54. This is a most unusual form of growth

Fig. 54.



Complex pyromorphite crystals, Edna May Gold Mine, Westonia.

and can only be accounted for by a sudden change in the concentration of the depositing solution at the stage represented by the completion of the growth of the larger prisms and the inception of the growth of the small prisms surmounting them.

Under the microscope the crystals are translucent, of varying tints of amber yellow and greenish yellow. In mass the crystalline crusts vary in tint from yellow to yellowish green. They dissolve readily in warm dilute nitric acid, and the solution gives strong reactions for lead, chloride, and phosphate ions. No arsenic, vanadium, chromium, molybdenum or tungsten could be detected in solutions of the mineral.

SULPHATES, TUNGSTATES, ETC.

Gypsum (Hydrated sulphate of calcium).—This was seen in only one specimen [1/1264], a sulphide ore from the Hill End G.M., consisting of a cellular mixture of pyrite and quartz. Many of the cavities in this ore are more or less completely filled with crystalline masses of gypsum coloured brown by included iron hydrates.

Epsomite (Hydrated sulphate of magnesium).—Scattered through the weathered rocks (*vide* Halite, p. 229).

Crocoite (Chromate of lead).—At the 170 feet level of the Edna May Mine Mr. Blatchford collected a small specimen of vughy quartz (leached pegmatite) studded with coarse gold and carrying several small crystalline masses of typical crocoite of orange-red colour and adamantine lustre. It is associated with thin films of green miloschite (chromiferous kaolinite). The crystals are small and imperfectly developed, so that only the unit prism and basal plane could be detected with certainty. A few very small crystalline masses of crocoite were also observed in association with much pyromorphite in a specimen of highly auriferous quartz from the 225 feet level of the same mine. The only other locality in the State from which specimens have been obtained showing free gold in association with crocoite is Comet Vale.

The crocoite found under such circumstances is undoubtedly a secondary mineral confined to the weathered zone of the ore body. Its origin can be traced ultimately to the galena of the sulphide ore and the chromite of the basic wall rock. Several intermediate stages must, however, be passed through between the ultimate crocoite and the two primary minerals. The galena is first oxidised to anglesite (lead sulphate) which is moderately soluble in water, viz. one part in 12,000 of water. The chromite, or its derivatives, fuchsite or miloschite, is probably attacked by the sulphuric acid of decomposing pyrites, yielding a solution of chromium sulphate, which in turn interacts with the lead sulphate in the presence of dissolved atmospheric oxygen yielding the much more insoluble lead chromate, crocoite.* The reactions are:—

$$(1)\quad \underset{\text{Galena}}{PbS} + \underset{\text{Oxygen}}{4O} \rightarrow \underset{\text{Anglesite}}{PbSO_4}$$

$$(2)\quad \underset{\text{Anglesite}}{2PbSO_4} + \underset{\substack{\text{Chromium}\\\text{Sulphate}}}{Cr_2(SO_4)_3} + \underset{\text{Water}}{5H_2O} + \underset{\text{Oxygen}}{3O} \rightarrow \underset{\text{Crocoite}}{2PbCrO_4} + \underset{\substack{\text{Sulphuric}\\\text{Acid}}}{5H_3SO_4}$$

Wolfram (Tungstate of iron and manganese).—This mineral is not uncommon in the auriferous pegmatites of the mines of the Edna May Group. Specimens have been collected in the Edna May, Edna May Central, and Edna May Deeps mines. It is a primary constituent of the veins in crystalline masses up to 2lbs. (one kilo) in weight, intergrown with quartz, and, below water level, with pyrite. In one specimen from the Edna May mine it is seen intergrown with much biotite and pyrite in a segregation in pegmatitic quartz. Gold has been observed embedded in wolfram in the same mine.

The mineral from the sulphide zone is perfectly fresh, with brilliant lustre on the cleavages. In the zone of oxidation the mineral has been much affected by the oxidation of the associated pyrite, the resulting acid having penetrated along the cleavages, dissolving out part of the mineral and leaving the remnant cellular and dull in lustre. In most cases the products of alteration have been completely removed, but in two specimens a little ferritungstite remains. (*Vide* Ferritungstite, p. 258, and Wulfenite, p. 258.)

Scheelite (Tungstate of calcium).—Masses of scheelite, up to several inches in diameter and in some considerable abundance, have been encountered in a pegmatite vein at a depth of 550 feet (168 metres) in the Edna May Deeps mine. The pegmatite is coarsely crystallised and composed of quartz, microcline, a felspar with albite twinning, red-brown biotite, chlorite, scheelite, wolfram, and pyrite. The scheelite has a coarsely granular structure, and is yellowish white in colour with adamantine lustre. It encloses grains of biotite and wolfram, and is evidently a product of the primary consolidation of the pegmatite. Should any considerable tonnage of ore be disclosed of the grade of the samples submitted it should be worth concentrating at the present price of tungsten ores, viz., 50s. per unit for concentrates with a minimum of 65 per cent. tungstic oxide.

Wulfenite (Molybdate of lead).—At the latter end of 1915, Mr. H. G. Stokes forwarded to me a small specimen of a heavy yellowish mineral in small crystals lining cavities in a six-inch (15 cm.) quartz vein traversing the Edna May gneiss. The mineral was locally presumed to be scheelite. The exact locality of the find was on the Edna May Deeps property at a depth of 70 to 80 feet (21 to 24 metres) in the workings from the No. 4 shaft. The mineral as proved to contain lead and tungstic acid and found to have the stalline form characteristic of stolzite, the native lead tungstate. der the heading, therefore, of Stolzite a brief preliminary note erring to this find was made in my annual report for 1915.* nce that time a fine suite of specimens of the mineral has been ained from those workings, which has enabled a more thorough

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* Solubilities in 1.000 cc. water at 18° are: lead sulphate, 41 milligrammes; lead chromate one-fifth of a milligramme.

Fig. 55.

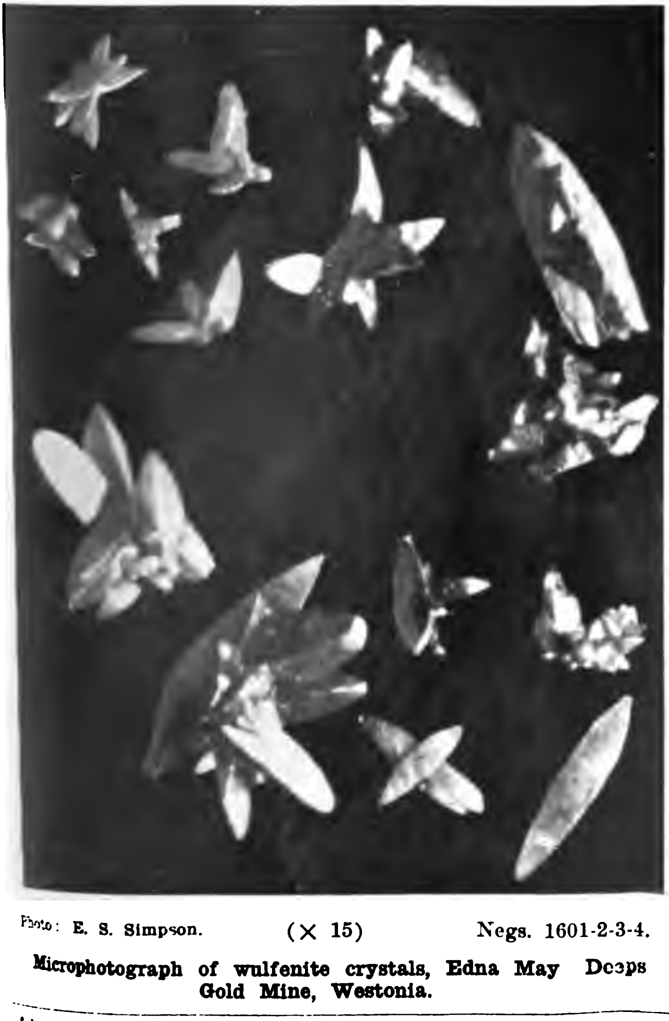

Photo: E. S. Simpson. (× 15) Negs. 1601-2-3-4.

Microphotograph of wulfenite crystals, Edna May Deeps Gold Mine, Westonia.

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* Ann. Prog. Rept. Geol. Surv., W.A., 1915, p. 37.

examination to be made. This has shown that, in addition to tungstic acid, molybdic acid is present, and that in excess, so that the mineral must be classified as a tungstiferous molybdate of lead i.e., as tungstiferous wulfenite.

The matrix of the mineral is a very cellular rubbly quartz somewhat ironstained and enclosed within walls of completely kaolinised gneiss. The cavities represent spaces once filled with sulphides (galena and pyrite) and possibly microcline, all of which have been completely weathered and, except for some kaolin, removed. No galena or molybdenite has been located in these workings, but pyrite and wolfram have been collected at lower levels in the vein.

The wulfenite occurs in masses of very small crystals with a general yellowish-grey colour, forming thick or thin discontinuous crusts on fracture planes and the sides of small cavities. Owing to the prevalence of kaolin through the vein the wulfenite crystals are often readily detached, and a fairly clean collection of them can be obtained by washing well in water, drying, and floating off associated quartz, etc., by means of undiluted methylene iodide. The largest crystals attain a length of 4mm. with a diameter of 2mm. (1/6 by 1/12 inch) but the average is only about a quarter of that size or even less.

With a view to getting some pure mineral for analysis, 24ozs. (680 grammes) of quartz specimens were lightly crushed to pass a 10-mesh sieve, and then concentrated by water in a batea, and the concentrates further cleaned, after drying, by means of methylene iodide of density 3.3. The yield was 66 grammes of fairly pure wulfenite, equal to 9.7 per cent. of the specimens taken. The concentrates having been washed successively with xylol, alcohol and ether were separated into sizes by means of a series of sieves. Each sized lot was examined separately under the microscope and two lots, viz., that passing a 30-mesh sieve but retained on a 60, and that passing a 60 but retained on a 90, were chosen as most likely to yield suitable material for analysis. The finer lot was covered with undiluted methylene iodide, and a little floating material decanted. In addition, by a vanning process under the methylene iodide, an appreciable quantity of minerals with a density between that of the liquid and that of the wulfenite, was removed. This latter material was chiefly iron hydrates, impure chrysocolla and intergrowths of quartz and wulfenite. After thorough washing with xylol, alcohol, and ether successively, the dried and slightly impure mineral was reserved for analysis as Lot B. The material which passed a 30-mesh but was held on a 60-mesh sieve was placed under a microscope and a little over one gramme weight of single crystals, and crystal groups similar to those shown in Fig. 55 were picked out for analysis. This apparently pure material was called Lot A. Density determinations and analyses were made of both lots.

Lot A gave an insoluble residue amounting to 0.36 per cent., the whole of which was clean quartz. In Lot B, after totalling up the oxides of lead, molybdenum, tungsten, and chromium, the total was still 3.17 per cent. short of 100. Of this, 0.58 per cent. was found to be quartz, the balance being iron hydrates, chrysocolla, etc. The figures for the essential constituents were recalculated after deducting 0.36 per cent. quartz in Lot A, and 3.17 per cent. quartz, etc., in Lot B. The results are shown in the accompanying table, together with the corresponding figures for related minerals.

Notes on the methods of analysis adopted will be found on page 259.

Analyses of Wulfenite and Related Minerals.

No.	I.	II.	III.	IV.	V.	VI.		VII.	
Mineral.	Wulfenite.	Stolzite.	Pb (Mo,W)O_4, 1 : 1.	Chillagite.	Chillagite.	Wulfenite A.		Wulfenite B.	
Locality.	Theory.	Theory.	Theory.	Chillagoe.	Chillagoe.	Westonia.		Westonia.	
	%	%	%	%	%	%	mols.	%	mols.
Lead oxide, PbO	60·8	49·2	54·3	54·36	54·09	59·76	268	60·36	270
Molybdic oxide, MoO_3 ..	39·2	..	17·5	19·44	16·32	35·55	247 }	34·68	241 }
Tungstic oxide, WO_3	..	50·8	28·2	24·24	29·52	4·31	19 } 268	4·77	21 } 264
Chromic oxide, CrO_3	..	..	..	..	..	·18	2 }	·19	2 }
Total	100·0	100·0	100·0	98·18	100·13	99·80	..	100·00	..
Density	6·70	8·20	7·45	7·3 ±	..	6·864	..	..	..
Analyst	..	..	..	Mingaye.	Mingaye.	Simpson.	..	Simpson.	..

I.—Theoretical composition and density of $PbMoO_4$.
II.— Do. do. $PbWO_4$.
III.— Do. do. ($PbMoO_4$ + $PbWO_4$).
IV.—"Chillagite," tungstiferous wulfenite, Chillagoe, Queensland. The density of the material analysed was not determined by Mingaye, but J. B. Henderson obtained a density of 7·30 for similar chillagite containing 23·5 % WO_3. The total includes 0·14 % of gangue. *See* Mingaye, J. C. H.; "Notes on Chillagite" Rec. G.S., N.S.W., **9**, 171. Henderson, J. B., "Interesting Mineral Specimens," Q. Govt., Min. Jour., **18**, 56.
V.—"Chillagite," molybdiferous stolzite, Chillagoe. Total includes 0·20 % of gangue.
VI. Picked crystals of Westonia wulfenite. Results for composition and density recalculated after deducting 0·36 % quartz.
VII.—Impure crystals of Westonia wulfenite separated by CH_2I_2. Results recalculated after deducting 3·17 % quartz, etc. The molecular excess of PbO may be due to the presence of a little $PbSO_4$ and PbS.

The mineral throughout, including that used for analysis, though at first sight to the unaided eye of a uniform greyish yellow colour, was seen under the microscope to be somewhat variable in this respect, ranging from almost colourless to rich honey yellow on the one hand, and through light and dark grey to almost black on the other. A little of the latter must have been present in Lot B, which was not hand picked, but any crystals of a grey or darker tinge were kept out of Lot A, as such were suspected of containing traces of lead sulphide and possibly lead sulphate. The lustre in all cases was adamantine, the translucency ranging from subtransparent to opaque.

Excluding the dark grey and black crystals, the composition of the remainder must be very uniform judging by the results of analyses made on the two lots selected in such different ways. The figures show that the Westonia mineral differs appreciably from normal wulfenite, such as the type mineral from Bleiberg in Carinthia, in containing nearly 10 per cent. of lead tungstate. The only previously described mineral containing both tungstate and molybdate of lead is the so-called Chillagite from North Queensland, which both A. T. Ullmann[*] and C. D. Smith and L. A. Cotton[†] are disposed to look upon as a "new mineral." It is not clear whether by this expression they mean a new mineral species, but if so there is little ground for such an assumption. Lead tungstate and lead molybdate both crystallise in the same (tetragonal) system with axial ratios almost identical (1.5616, stolzite; and 1.5770, wulfenite), and their molecular volumes are also very close (55.5, stolzite; and 54.8, wulfenite). Further, the two compounds are precipitated under similar conditions and their solubilities are of the same order. Under such conditions it would be surprising indeed if a complete isomorphous series were not found extending from pure tungstate on the one hand to pure molybdate on the other. The Westonia mineral and the two quoted Chillagoe minerals are three stages in this series.

The less probable alternative is that a true double salt exists, having the composition $PbMoO_4.PbWO_4$, and yielding a definite cusp in the curves representing the values of any physical property, such as the density, refractive index, or length of the principal axis; or of any chemical property, such as the solubility. No such cusp is indicated in the case of the densities which appear to obey the usual hyperbolic law, but Smith and Cotton's figure[‡] for the mean length of the principal axis in chillagite (1.5292) would indicate a very distinct cusp in the curve for that factor. Their figures, however, need careful checking since their readings of polar distances are associated with errors in azimuth angle often exceeding one degree, and there is some slight doubt about the symbol of the face on which they based their calculation. No instrument of sufficient pr cision was available for measurement of the axial ratio for tl Westonia mineral.

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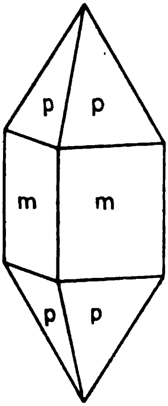
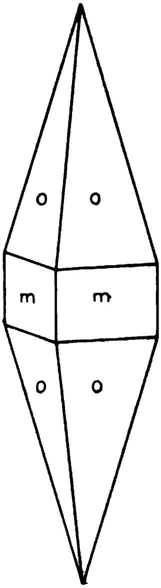
[*] Ullmann, A. T., Jour. Roy. Soc., N.S.W., 1912, 46, 186.
[†] Smith, C. D., and Cotton, L. A., *Ibid.*, p. 219.
[‡] Loc. cit.

Fig. 56.



Common form of wulfenite crystals, Edna May Deeps Gold Mine, Westonia.

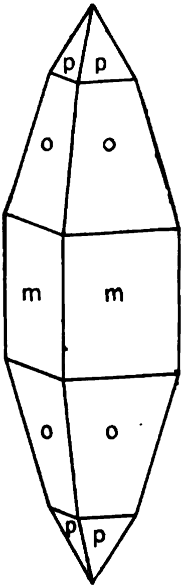
Fig. 57.



Common form of wulfenite crystals, Edna May Deeps Gold Mine, Westonia.

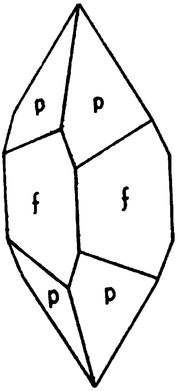
Assuming that no double salt exists, the Westonia mineral is an isomorphous mixture of wulfenite and stolzite. So, too, is chillagite, which at most is to be looked upon as a subspecies, defined as

Fig. 58.



Common form of wulfenite crystals, Edna May Deeps Gold Mine, Westonia.

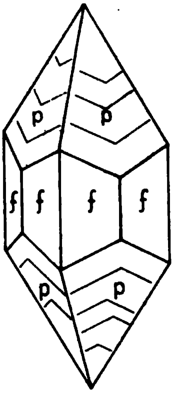
Fig. 59.



Rare Form of wulfenite crystals, Edna May Deeps Gold Mine, Westonia.

including all crystallised molecular mixtures of wulfenite and stolzite approaching equal molecular proportions of the two components.

Fig. 60.



Rare Form of wulfenite crystals, Edna May Deeps Gold Mine, Westonia.

The crystallisation of the Westonia wulfenite is of interest and is illustrated by Figs. 55 to 60. Normally wulfenite crystallises in thin tabular crystals bounded by broad basal pinacoids or low pyramids, and with little or no development of faces in the prism zone. This is the form seen in wulfenite from Whim Creek, Western Australia, as well as in chillagite from Chillagoe, Queensland. Stolzite, on the other hand, is characterised by the large development of prism faces and steep pyramids. This is the type of crystal exhibited by the Westonia mineral, of which Figs. 56, 57, 58 show common forms, and Figs. 59, 60 rarer ones. The complete list of forms recorded for minerals of this series are collected together for the first time in the accompanying table. The forms most frequently present in the Westonia mineral are m (110), p (111), and o (221): of much rarer occurrence are c (001), e (101), and f (320). The faces of p are often striated by lines parallel to the edges pf, *see* Fig. 60. Other forms will doubtless be recognised when the crystals are subjected to rigid measurement.

CRYSTALLOGRAPHIC DATA FOR WULFENITE-STOLZITE SERIES.

Vertical Axis.

Wulfenite: 1·57645 (Lacroix); 1·5771 (Dauber); 1·5774 (Goldschmidt)—Mean, 1·5770.

Stolzite: 1·5576 (Zt. Krst, 1907); 1·5579, 1·5586, 1·5597, 1·5606, 1·5613, 1·5631 (Hlawatsch); 1·5667 (Kerndt); 1·5692 (A. Levy)—Mean, 1·5616.

Chillagite: 1·5291 ? (Smith and Cotton).

Forms.

Letter.	Symbol.	Wulfenite.	Stolzite.	Chillagite.	Westonia Mineral.
c	001	×	×	×	×
a	100	×	×	—	—
m	110	×	×	—	×
n	650	×	—	—	—
[illegible]	430	×	—	—	—
f	320	×	—	—	×
[illegible]	530	×	—	—	—
l	740	×	—	—	—
k	210	×	—	—	—
g	310	×	—	—	—
[illegible]	1·0·264	×	—	—	—
b	1·0·16	×	—	—	—
β	1·0·12	×	—	—	—
[illegible]	109	—	×	—	—
t	103	×	×	×	—
z	205	×	—	—	—
.. .. ..	5·0·11	×	—	—	—
u (o)	102	×	×	—	—
v (η)	203	×	×	—	—
h	304	—	×	—	—
e	101	×	×	×	×
[illegible] (θ)	302	×	—	×	—
[illegible] (p)	201	×	×	—	—
X	904	—	—	×	—
Y	1·1·18	—	—	×	—
w	1·1·16	×	—	—	—
[illegible]	1·1·12	×	—	—	—
[illegible]	1·1·10	—	—	×	—
y	119	—	×	×	—
z	2·2·17	—	—	×	—
v (l)	118	×	—	×	—
[illegible] (k)	117	×	×	×	—
g	116	—	—	×	—
G	2·2·11	—	—	×	—
F	3·3·16	—	—	×	—
f	115	—	×	×	—
t	229	×	—	—	—
d	114	—	—	×	—
D	6·6·23	—	—	×	—
s (b)	113	×	×	×	—

CRYSTALLOGRAPHIC DATA FOR WULFENITE-STOLZITE SERIES—*continued.*

Forms—continued.

Letter.	Symbol.	Wulfenite.	Stolzite.	Chillagite.	Westonia Mineral.
w	225	—	—	×	—
v	112	—	×	—	—
p (n)	111	×	×	×	×
γ	443	×	—	—	—
r	332	×	—	—	—
o (d)	221	×	×	—	×
λ (x)	311	×	×	—	—
x	343	—	—	×	—
.. .. ..	977	×	—	—	—
z	277	—	—	×	—
.. .. ..	233	—	×	—	—
π	313	×	×	×	—
A	515	—	×	—	—
ζ	432	×	×	—	—
φ	7·1·75	×	—	—	—
Ψ	8·9·18	×	—	—	—

The genesis of the Westonia wulfenite is to be ascribed to interaction, in the zone of weathering, between solutions of lead sulphate derived from weathering galena, and of molybdic acid from weathering molybdenite, and tungstic acid derived from weathering mixtures of pyrite and wolfram, such as occur in the Edna May mine (see p. 248), thus:

$PbSO_4 + (Mo.W)O_3 \cdot xH_2O$ yield $Pb(Mo,W)O_4 + H_2SO_4 + (x\text{-}1)\,H_2O$
Lead Sulphate. Molybdic acid Tungstic acid. Tungstiferous Wulfenite. Sulphuric acid. Water.

Ferritungstite (Hydrated tungstate of iron).—A small amount of a bright yellow powder on the surface of partly leached wolfram (*q.v.*) from the Edna May Central and the Edna May Deeps [1/34], was proved to contain both tungsten and iron, and is therefore undoubtedly ferritungstite. Its association with wolfram, which has been partly leached by sulphuric acid from decomposing pyrite, points to its origin by the hydrolysis of solutions carrying iron sulphates and colloidal and dissolved tungstic acid. The reactions involved are:

$FeWO_4 + FeSO_4 + 2H_2SO_4 + O + 7H_2O$ yield
Wolfram Ferrous Sulphate. Sulphuric acid. Oxygen. Water.

$Fe_2(SO_4)_3 + WO_3 \cdot 2H_2O + 7H_2O$ yielding in turn
Ferric Sulphate. Tungstic acid. Water.

$Fe_2WO_6 \cdot 6H_2O + 3H_2SO_4$
Ferritungstite Sulphuric acid.

ADDENDUM.

ANALYTICAL METHODS FOR TUNGSTIFEROUS WULFENITE AND FOR MILOSCHITE.

Note.—All operations are carried out in beakers or dishes of platinum or transparent silica, and all reagents are tested quantatively for impurities before use. The following schemes are designed to enable analyses to be made on minimum quantities of the minerals.

TUNGSTIFEROUS WULFENITE.

A. **Lead and Combined Acids.**—Half a gram of the mineral, finely ground, is treated with 20cc. 10E.HCl at 90°-95° C. for 30 minutes, when solution is complete. Add 150cc. of water, and heat to 60°. Add 25cc. $15E.NH_4HO$ * and immediately pass H_2S for two hours. Warm to 60° and filter off PbS plus $Cr_2(HO)_6$ plus quartz. Wash with 100cc. warm water to which 10 drops yellow ammonium sulphide have been added and H_2S then passed through it (the wash water) for a minute. The filtrate, which is a deep garnet red in colour, contains all Mo and W as sulpho-salts. To this add $5E.H_2SO_4$ in small quantities at a time until the solution contains an excess of about 1cc. of this acid. Warm to 80° for about two hours, the beaker being covered to avoid loss of much H_2S, and filter off WS_3 plus MoS_3. Wash with warm H_2S water. Then wash all but traces of the sulphides off the filter into a beaker and put filter into a flat dish and warm with several successive lots of $5E.HNO_3$ until all sulphide is dissolved. Add the washings to main precipitate. Cover and add $16E.HNO_3$ and warm until no further effervescence occurs. Evaporate to fumes of SO_3 (formed by action of HNO_3 on sulphides). Take up with $5E.NH_4HO$ and transfer solution and sediment † to a weighed 30cc. porcelain capsule. Evaporate to dryness on a sandbath and gradually increase the temperature first on sandbath and then over argand to remove all NH_4 salts. Finally ignite with a moving bunsen flame at a temperature well below red heat (MoO_3 volatilises at about 640°) until residue of molybdic and tungstic oxides loses all blue or green colour. Weigh $MoO_3 + WO_3$.

The precipitated PbS with any traces of $Cr_2(OH)_6$ and quartz is washed off filter into a beaker, and the filter treated with warm $5E.HNO_3$ and finally with water as in the case of the MoS_3 to get last traces of lead into solution. Add these washings to the main precipitate. Convert all the PbS into $PbSO_4$ by boiling with HNO_3, then adding 20cc. $10E.H_2SO_4$ and evaporate to fumes, continuing fuming gently until all globules of sulphur are oxidised.

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* This causes a precipitation of very finely divided $PbWO_4$ and $PbMoO^4$.
† Undissolved WO_3xH_2O.

Dilute to 5E strength in acid, add 50cc. 5E.H_2SO_4, boil, cool, add 50cc. absolute alcohol and set aside at a temperature of about 15° all night. Filter off $PbSO_4$ plus quartz. Wash twice with 90 per cent. alcohol. Redissolve the $PbSO_4$ in warm ammonium acetate, and filter through original filter. Ignite filter and weigh quartz. In filtrate, reprecipitate $PbSO_4$ by evaporating to fumes with H_2SO_4 and taking up as before with 5E.H_2SO_4, and adding alcohol. Filter, dry, and ignite in porcelain capsule to a faint red with the usual precautions and weigh $PbSO_4$. $Pb/PbSO_4$, 0.7360.

When quartz is absent, or is in very small amounts, and weighed as described in section B, the solution and reprecipitation of the $PbSO_4$ is unnecessary, the weight of the quartz being simply deducted from the combined weight of the two.

B.—**Tungstic Oxide and Chromic Oxide.**—Take a separate lot of finely ground mineral (0.5 or 1.0 gm.) and treat with 30*cc.* 5E.HNO_3 at 95° for an hour. Filter and wash with one lot of 5E.HNO_3. Solution contains part of Pb, Mo and Cr, but no W: residue contains some undecomposed mineral and some $MoO_3.2H_2O$, and $WO_3.H_2O$. Pass 10cc. 5E.NH_4HO through filter and catch in the beaker containing the residue. Shake beaker till all separated $WO_3.H_2O$ and $MoO_3.2H_2O$ are dissolved. Pour 1cc. 5E.HNO_3 through filter, catching it in the beaker containing the residue, to which then add 20cc. 10E.HNO_3. The solution now measures 31cc. and is again of 5E strength in nitric acid. Again heat to 95° for one hour. It will be seen that the original acidification precipitates white flocculent $WO_3.2H_2O$ which during the subsequent heating is converted into bright yellow granular $WO_3.H_2O$. Filter, etc., as before. Mix the two acid extracts which contain practically all the CrO_3* and estimate this by colour comparison with measured quantities of standard K_2CrO_4 solution recently diluted with 5E.HNO_3.

The alternate treatment of the residue with 5E.HNO_3 and 5E.NH_4HO is repeated altogether five times, the same beaker and small filter being used throughout. After this treatment the whole of the Pb, Mo, and Cr will be in the nitric solution, and the whole of the W (and any siliceous gangue) left in the yellow residue of $WO_3.H_2O$. This residue is dissolved in 5E.NH_4HO, filtered from the quartz, the filter washed with 5E.NH_4HO, and the filtrate evaporated to dryness in a weighed 30cc. porcelain capsule and cautiously heated till all ammonia salts are driven off. The residue is ignited over a bunsen at a bright red heat and weighed as WO_3. Should the MoO_3 not have been completely separated, its presence will be indicated by the bluish-black colour of the just dry residue of ammonium tungstate, when it is first heated to about 200° to decompose ammonia salts.

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* To ensure that this solution contains no traces of WO_3 which might affect the colour, it may be diluted with its own volume of water, boiled, and allowed to stand overnight, when any trace of WO_3 will be found to have settled out.

Complete decomposition of the mineral can be recognised usually after the fourth treatment, by no insoluble, except quartz, being left on adding the 10cc. of 5E.NH_4HO to the residue left by the acid treatment.

The above method can be applied to the estimation of tungsten and molybdenum in a number of minerals, in fact in any mineral decomposable by nitric acid of any strength, such as scheelite, powellite, bismuth ochres, etc. When stronger acid than 5E has to be used to attack the mineral, it is diluted subsequently to 5E strength and kept at 90° to 95° for an hour before filtering, as this ensures the complete separation of insoluble tungstic acid.

MILOSCHITE.

The mineral is first well soaked and washed with distilled water to remove common salt, magnesium sulphate, etc., derived from saline underground waters, and then dried at atmospheric temperature for three or four days.

A. **Moisture, combined water, chromium, titanium and iron oxides.**—Half a gram of the mineral is dried at 100°, using a pair of ground watch-glasses, and the moisture determined by loss.

The dried mineral is carefully transferred to a weighed 20-25cc. platinum crucible. This is heated for a few minutes on a wire gauze and afterwards over a méker to constant weight, and the loss taken as combined water. Note: no further loss was experienced on subsequent ignition over an air-coal gas blast.

To the ignited mineral add 1.5 gram anhydrous sodium carbonate, mix, and heat over a bunsen for an hour with the lid on, setting the crucible on a small disc of platinum foil supported on a platinum triangle to avoid over-heating of the bottom of the crucible. The lid should be raised one or twice to admit atmospheric oxygen. Moisten the frit and grind it with a little water and one drop of alcohol* in a small agate mortar. Extract with several lots of boiling water totalling not more than 50cc., and filter. Dry the filter and residue in the original platinum crucible and burn off filter at a low temperature. Then add 1.5 gram sodium carbonate and 0.5 gram sodium peroxide, refrit and again extract. Determine the CrO_3 in each extract colorimetrically and calculate to Cr_2O_3. Note: on testing this solution for V_2O_5 none was found.

Put filter and residue in a beaker and add about 30cc. 5E.H_2SO_4, and warm till solution is complete. Filter, and in the filtrate estimate the Ti colorimetrically after adding H_2O_2. Boil down until all colour is destroyed, dilute to 50cc., boil, cool, and estimate the iron colorimetrically with NH_4CNS.

B. **Silica, alumina, magnesia (manganese, lime).**—Following in general the lines laid down by Hillebrand, these are estimated in 0.5 gram of mineral after fusion with two grams of fusion mixture.

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* To destroy any manganate.

One evaporation only is made for silica, the silicic acid being washed with NH_4NO_3 water and extra silica recovered from the Group 3A precipitate. The main silica precipitate is treated with H_2SO_4 and HF, and the residue, after weighing, is fused with a little fusion mixture and added to the main solution. The 3A precipitate, after weighing, is heated to a red heat for an hour with one gram of fusion mixture, taken up with 5E.HCl, evaporated to dryness, taken up with HCl, and the extra silica filtered and washed with NH_4NO_3 water. This small amount of impure silica is weighed and then evaporated with H_2SO_4 and HF, and the residue ignited and weighed.

Double precipitations are made of the 3A* and magnesia precipitates. Neither manganese nor lime were detected in the Westonia mineral.

C. **Alkalies.**—These are determined by the Lawrence Smith method, with one slight but valuable modification introduced some years ago in this laboratory by Mr. H. Bowley, Assistant Mineralogist and Chemist. The original fritting is not made with $CaCO_3$ and NH_4Cl alone, but with a mixture of $CaCO_3$, CaO, and NH_4Cl, the mixture of $CaCO_3$ and CaO being obtained by a preliminary ignition for two minutes of the usual six parts of $CaCO_3$. In every other respect the usual details are followed, the mixed alkalies being weighed as chlorides, and the potassium as chloroplatinate. In this, as in all other estimations, the results of a blank test are deducted.

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* With ammonium acetate.

SECTION D.

THE PETROLOGY OF WESTONIA,

with Notes on Rocks from

BULLFINCH, GOLDEN VALLEY, HATTER'S HILL, AND THE CORINTHIAN MINE,

by

R. A. Farquharson, M.A. (Oxon.), M.Sc., A.O.S.M.

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I.—INTRODUCTION AND PREVIOUS LITERATURE.

The investigation of the rocks and the geological structure of the Westonia Field, as in the case of many other Western Australian goldfields, has been attended with considerable difficulty. This has been due to the paucity of outcrops, to the prevailing layer of overburden on the whole surface, to the decomposed nature of the rocks even when found outcropping, and in consequence, to the necessity of relying mainly on evidence from specimens procured in mines and bore cores—evidence which must obviously be used with much greater care than is required when continuous outcrops can be examined. A large number of specimens, however, have been examined and the microscopical results have in all cases been considered and discussed in relation to the field evidence, so that the conclusions arrived at are those best in accordance with the facts that the present state of the development of the mines and the field permits to be obtained. Several points have arisen in the course of the investigations which will be satisfactorily cleared up only by further opening up of the field and developments at deeper levels in the mines. These are noted in the text.

With regard to previous literature dealing with the Westonia Field, there does not appear to be any, so that this account of the Petrology of the goldfield is the first that has hitherto been published.

II.—CLASSIFICATION OF THE ROCKS.

As the specimens come from localities scattered over a fairly wide area, it has been found most convenient to classify them broadly according to the locality from which they come. On this basis there are the following divisions:—

A. Rocks from Westonia (including the Hill End and Battler Leases).
B. The Dolerite Dykes from the Corinthian Mine.
C. Rocks from the Bullfinch Area.
D. Greenstones from Golden Valley.
E. Greenstones from Hatter's Hill.
F. Some Graphitised Rocks of doubtful origin from the Comstock Leases, etc.

Division A, the Rocks from Westonia, which comprises by far the most diversified and important types in the whole area examined, is sub-divided on a petrological basis into the following groups:—

1. The Greenstone Dykes.
2. The Country Greenstone Rocks.
3. The nature of the Country Greenstone Rocks and their mutual relations.
4. The Gray Biotite-Gneiss of the Lens of the Main Lode.
5. The Quartz Specimens.
6. The Granites.
7. The Aplite or White Granite Dykes.
8. The Hill End and Battler Gneiss.

III.—DESCRIPTION OF THE ROCKS.

A.—THE ROCKS FROM WESTONIA (INCLUDING THE HILL END AND BATTLER LEASES).

1.—The Greenstone Dykes.

From the field occurrences as observed by Mr. Blatchford various greenstone rocks occur undeniably as dykes, while others have field relations that are somewhat doubtful though possessing general microscopic characters to some extent similar to rocks that are certainly dykes. Microscopic investigation, therefore, has been made of these various rock specimens with the object of ascertaining (a) the characters of the specimens, (b) their relationships one to the other, and the extent to which they may be correlated and established as continuous or parallel and genetically similar dykes, or as identical dykes at different levels. Since it is a very well known fact that in greenstone areas such apparently diverse types of rock as hornblendite, epidiorite and hornblende schist may all occur as mere variations of one large mass, passing by almost insensible gradations from one into the other, it will be realised that it is extremely difficult to draw any hard and fast line of demarcation as genetically different dykes between greenstone specimens on a basis, say, of the presence or absence of felspar, or the occurrence of a certain degree of foliation or even on the presence or absence of quartz. It is only, indeed, by careful consideration, not alone of the differences, but also of the resemblances both mineralogical and structural, and equally important, of the mode of occurrence of the rocks that reliable conclusions as to the relation between them can be arrived at. In many cases, even then, subsequent developments may necessitate a modification of the original views, especially when the evidence formerly existing has not been as clear as the importance of the questions involved rendered desirable.

In the present case, not only with regard to the greenstone dykes but with regard to all the groups of rocks from the area under consideration, the conclusions arrived at have been based on the evidence afforded both by the mineralogical and structural differences and resemblances between the specimens and by the circumstances of occurrence in the field, or in the mines.

Briefly, the result has been, in the case of the greenstone dykes, the formation of the following groups:—

(a) That of specimens $[\frac{1}{860}]$, $[\frac{1}{861}]$, $[\frac{1}{862}]$, $[\frac{1}{863}]$, $[\frac{1}{864}]$, $[\frac{1}{865}]$ and $[\frac{1}{866}]$.

(b) That of the specimens $[\frac{1}{867}]$ and $[\frac{1}{868}]$ from the Depressed Bore from Edna May Deeps.

(c) That of specimen $[\frac{1}{869}]$.

(d) That of $[\frac{1}{870}]$ and $[\frac{1}{871}]$, and the bore core at 364 feet in Duff's Bore, Edna May Deeps—$[\frac{1}{872}]$.

Character of the Specimens:—

[a] The characters of the group may be best studied in $[\frac{1}{863}]$ and $[\frac{1}{864}]$.

$[\frac{1}{863}]$ From South Crosscut, 225ft. level, Edna May Mine.

This is a platy prismatic hornblendite consisting entirely of a rather coarse plexus of platy crystals and platy prisms of rather pale green actinolitic hornblende with the interstices occupied by a little pleochroic reddish chlorite, which in places approximates in optical characters to biotite. There are grains of pyrrhotite and smaller grains of magnetite scattered over the slide. (Fig. 61.)

$[\frac{1}{864}]$ From the Main Crosscut, 300ft. level, Edna May.

This rock is identical with $[\frac{1}{863}]$ both in composition and structure being only slightly coarser in grain.

$[\frac{1}{865}\text{A}]$. From Edna May Deeps, 485ft. level, side of Drive.

This is an actinolitic chloritic hornblendite, rather fine-grained, consisting of a mass or indistinct plexus of small ragged prisms and plates of pale green hornblende with interstitial pleochroic flakes of reddish-yellow chlorite. A very small amount of granular iron ore (pyrites, etc.) is sometimes visible.

$[\frac{1}{865}\text{B}]$. From the same Mine, but from the Winze at the 480ft. level.

This is very similar to $[\frac{1}{865}\text{A}]$, but is somewhat coarser and less platy, and with a more distinct plexus of prismatic hornblende forms. Sulphide ore (pyrrhotite, etc.) is also more common.

There can be little doubt that $[\frac{1}{865}\text{A}]$ and $[\frac{1}{865}\text{B}]$ are portions of the same rock mass,

$[\frac{1}{860}]$ and $[\frac{1}{20}]$. From End of main Crosscut, 150ft. level, Edna May.

This rock is considerably decomposed and hence, though its broad characters are fairly easy to determine, its relationship to fresher rocks is rather indistinct. It is, however, an actinolitic prismatic chloritic hornblendite. Neither quartz nor felspar was identified, and both the structure and composition agree closely with those of $[\frac{1}{863}]$ and $[\frac{1}{864}]$.

$[\frac{1}{861}.]$ From No. 3 South Crosscut, 150ft. Level, Edna May Mine.

This specimen is extremely decomposed, and it has only been after special treatment with balsam that a section of it has been obtainable. On account of the chemical and mineralogical alterations that have taken place in the rock, correlation of it is difficult, but, allowing for these, it appears to resemble closely $[\frac{1}{860}]$ above.

Fig. 61.

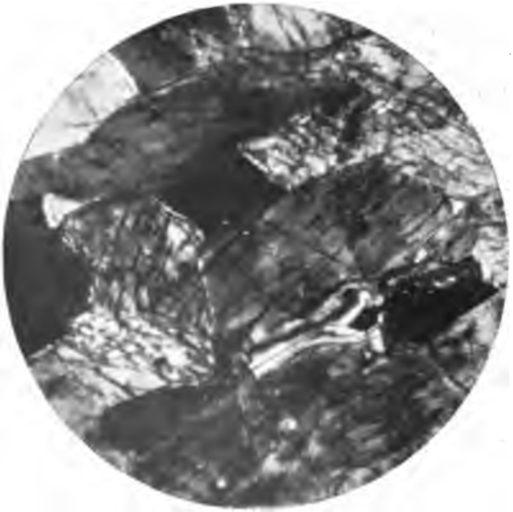

Photo: R. A. Farquharson. Neg. 1605.

$[\frac{1}{863}]$ **Prismatic hornblendite, showing the plexus of hornblende prisms.**

$[\frac{1}{862}.]$ From South Crosscut, near the Shaft, 150ft. Level, Edna May.

The specimen is another medium-grained prismatic hornblendite, similar to $[\frac{1}{861}]$, but with a very small amount of slightly turbid felspar developed.

$[\frac{1}{860}]$, $[\frac{1}{861}]$, and $[\frac{1}{862}]$ are therefore closely similar to one another.

[$\frac{1}{860}$.] From the End of East Drive, 150ft. Level, Edna May Mine.

This is a chloritic platy prismatic hornblendite which, owing to the presence of an amount of kaolinised felspar that, though very small relative to the hornblende, is yet greater than in [$\frac{1}{862}$], approximates to an epidiorite. The rock is finely schistose, in this respect and in the presence of felspar differing from [$\frac{1}{863}$] and [$\frac{1}{864}$]. In the appearance and structure of the hornblende, however, it resembles both [$\frac{1}{862}$] and [$\frac{1}{864}$], and as [$\frac{1}{862}$] also contains a little felspar, it may be regarded as an intermediate stage between [$\frac{1}{860}$] and [$\frac{1}{863}$].

(b.) This is represented by [$\frac{1}{867}$] and [$\frac{1}{868}$], from the Depressed Bore, Edna May Deeps Mine, and the Depr.sed Bore, Edna May Mine. [$\frac{1}{867}$], Edna May "Deeps" 470 feet. [$\frac{1}{868}$], Edna Depressed Bore V.D., 427 feet.

[$\frac{1}{867}$.] From 470ft. vertical, Edna May Deeps Mine.

This is a schistose rather fine-grained, elongated prismatic hornblendite rather resembling [$\frac{1}{863}$] and [$\frac{1}{864}$], but much finer in grain, and, in places, with very small elongated colourless patches of iridescent scales which, though difficult to determine, possibly represent felspar that has been kaolinised or micacised.

[$\frac{1}{868}$.] From Edna May Depressed Bore, 427ft.; is similar to [$\frac{1}{867}$] and calls for no individual description.

The important point with regard to these two specimens (which are identical) is to what are they related? Undoubtedly in structure and in the preponderance of hornblendic prisms and plates, they resemble [$\frac{1}{863}$] and [$\frac{1}{864}$] . Though in the two latter there is no trace of the clear patches, it must be remembered that [$\frac{1}{862}$] and [$\frac{1}{860}$]—specimens which are correlated with [$\frac{1}{863}$] and [$\frac{1}{864}$] — there are also clear patches, demonstrably felspar. Moreover, certain portions of the slides of [$\frac{1}{867}$], in which these patches are rare or non-existent, are scarcely distinguishable, except in size of grain, from sections of [$\frac{1}{863}$]. Again, the presence or absence of a small proportion of felspar in specimens from a greenstone complex cannot be regarded as a criterion of any weight so far as difference in origin is concerned, since in numerous cases all gradations have been traced from gabbros with appreciable felspar to pyroxenites with no felspar, and epidiorites and hornblendites have without doubt been derived by thermo-dynamic metamorphism from these rocks.

There is little doubt, therefore, that [$\frac{1}{867}$] and [$\frac{1}{868}$], though placed in a separate group (b), are to be correlated with group (a), and this conclusion is in accord with the suggestions of the field evidence.

(c) This group is represented by one specimen only:—

[$\frac{1}{869}$.] From south-west end of No. 2 Reef, 225ft. level, Edna May Mine.

The rock is extremely weathered, of a dirty yellowish colour and very friable. It is, therefore, very difficult to obtain a section of it, and it was only through treatment with balsam that this was practicable at all, while the section itself was only of indifferent value. The rock consists, however, of platy, granular, and fibrous aggregates of chloritised hornblende, mostly loose, with interspersed grains and small laths of generally twinned felspar and small grains of quartz. Some of the hornblendic aggregates are devoid of either felspar or quartz. The structure of the rock is too indefinite for correlation, but both it and the composition of the rock are not unlike what would be produced by the weathering of such a specimen as [$\frac{1}{860}$], if rather more felspar were present than is the case in [$\frac{1}{860}$]. The original was undoubtedly hornblendic and felspathic, and was probably a fine-grained epidiorite or amphibolite. It is placed in a separate group, partly on account of the indefiniteness of its petrological character due to decomposition, and partly owing to the definiteness of its occurrence as a dyke.

(d) The specimens included here are [$\frac{1}{870}$], [$\frac{1}{871}$], and tho bore core at 364ft. in Duff's Bore, Edna May Mine.

[$\frac{1}{870}$.] From the Depressed Bore, Edna Deeps Mine, 113ft.-115ft.

This is a fine-grained, green and brown facies consisting of a granular mass or aggregate of small plates and irregular small stout prisms of green hornblende—at times chloritised—numerous small irregular brown-red scales and scaly aggregates of biotitic chlorite associated with the green hornblende forms, and small prisms, plates, or, rarely, indistinct small columns of felspar occasionally partially kaolinised. In places in the slides the hornblende crystals form platy and stout prismatic aggregates to the exclusion of the other constitutents. Many of the micaceous flakes are in part brownish, in part green, as if the biotite forms were derived from green chlorite arising primarily from the hornblende. Numerous grains and aggregates of sphene occur in association with the hornblende. The structure of the slides is essentially fine granular, and a slight suggestion of parallel alignment of the constituents is noticeable in places.

The rock is a fine granular, biotitic and chloritic *hornblende-felspar amphibolite.*

[$\frac{1}{871}$.] From the 344ft. Level, Edna May Deeps Shaft.

The specimen shows a contact between a finely schistose, fine-grained dark-green rock and a coarser-grained grey granitic or gneissic rock with marked foliation. The fact that the strikes of the foliation in the two facies can be seen in hand specimens to meet at a pronounced angle is evidence that the two facies are not intimately related to one another as, for instance, basic and acid segregations, but that one is most probably a dyke in the other. (Fig. 62.) From the field evidence, the greenstone is the dyke.

This greenstone is in section a finely schistose rock consisting of small rods, plates or flakes of green hornblende elongated in numerous indistinct lines and associated with occasional brown-red biotitic flakes or rods and sphene granules, separated by a large number of partially kaolinised small felspar plates, with, in many cases, a similar parallel elongation. There are, however, many larger platy forms without definite alignment. The structure is fine-grained granular, finely schistose, and there is a preponderance of the colourless constituent. Quartz was not definitely recognised.

The rock is, therefore, a finely schistose, granular *hornblende-biotite-felspar amphibolite.*

[$\frac{1}{872}$.] Specimen from 364ft. in Duff's Bore, Edna May Deeps Mine.

This consists of a fine-grained aggregate of prisms and plates of greenish hornblende with a smaller amount of associated brown-red biotite and biotitic chlorite scales as a very loose plexus in which are small plates, thin and stout partially kaolinised columns of felspar, that are frequently partially moulded by the ferro-magnesian with the production in places of a suggestion of ophitic structure. (Fig. 63.)

Fig. 62.

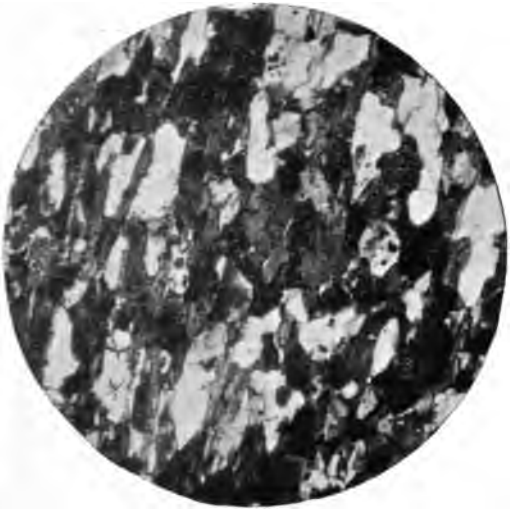

Photo: R. A. Farquharson. Neg. 1606.

[$\frac{1}{871}$] Showing a contact between a finely schistose dark-green hornblendite and a coarser-grained granitic or gneissic rock.

As in [$\frac{1}{870}$], there are patches that are aggregates exclusively of small plates and prisms of hornblende. A very small amount of interstitial quartz appears to be present.

The rock is a somewhat fine-grained *hornblende-biotite-felspar* rock probably best described as an amphibolite, with hornblende and felspar in nearly equal quantities.

From the descriptions it will seem that, except for the pronounced foliation or schistosity in [$\frac{1}{871}$], the three specimens [$\frac{1}{870}$], [$\frac{1}{871}$], and 364ft., agree very closely both in structure and mineral composition. Certainly when compared with the other rock facies of the whole field they form a distinct class by themselves, and since according to Mr. Blatchford, field observation supports a genetic connection between them, and indicates their occurrence as dykes, the whole of the evidence available warrants their being correlated together as the same or similar dykes.

The results of examination of the greenstone dykes, therefore, indicate the existence of three groups, viz.:—

Group 1 ; including $[\frac{1}{863}]$, $[\frac{1}{864}]$, etc., along with $[\frac{1}{867}]$ and $[\frac{1}{868}]$.

Group (b) thus merges into Group (a).

Group 2: including one specimen only, viz., $[\frac{1}{869}]$ which is separated on account of its extremely decomposed state and consequent indefinite petrological character, and on account of its very distinct occurrence as a dyke.

Group 3: including $[\frac{1}{870}]$, $[\frac{1}{871}]$, and the core specimen from 364ft. in Duff's Bore, Edna May "Deeps" Mine.

Fig. 63.

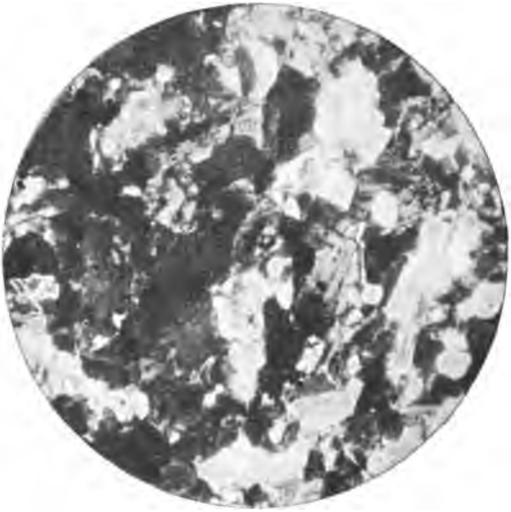

Photo: R. A. Farquharson. Neg. 1607.

$[\frac{1}{39}]$ 364ft. in Duff's Bore: Showing the fine-grained aggregate of prisms and plates of hornblende and small plates and columns of felspar.

2.—The Country Greenstone Rocks.

Owing to the extremely weathered character of the surface of the country and to the paucity of the outcrops, it is possible only in a few places to obtain specimens illustrating the geological constitution of the country in which the lens of the Main Lode occurs. As several bores, however, have been put down in connection with the mine workings, an examination of these has to a certain extent amplified the meagre evidence from the outcrops. The character of the rocks has been determined from the following sources of information:—

(1.) The outcrops themselves.
(2.) The Bore cores, particularly Duff's Bore, Edna May, the No. 3 Bore, Edna May, and the Bore put down in Weston's Reward Mine.
(3.) The section exposed in the Plat in the Edna May Mine at the 300ft. level.

(1.) *The Outcrops*:

(a.) The chief of these occurs as an ill-defined band mapped as a long attenuated lens with doubtful boundaries, extending from the Junction Lease, through the Edna May, Myrtle, Recovery, and Advance Leases and the South-West corner of G.M.L. 2079, disappearing at the north-west corner of the Elsie Lease. Whether it thins out to a vanishing point at this corner or merely disappears owing to being covered from view by the overburden is not at present determinable. The rocks of the outcrops are represented by:— **[13996]**, **[13997]**, **[13998]**, [$\frac{1}{15}$], [$\frac{1}{16}$], and by some slides furnished by Mr. Blatchford.

[**13996**] from G.M.L. 2081:—

This is a rather coarse-grained indistinctly foliated dark-green and white, dioritic rock, the green portions being composed of needles of hornblende in parallel alignment.

In section, the essential minerals present are hornblende, quartz, and felspar.

The hornblende occurs in ragged plates and prisms in imperfect bands, the crystals being more or less in parallel alignment and occasionally perforated by round quartz and felspar plates. In places, an alteration to greenish chlorite is visible, in places a brownish-red biotitic flake. Between the hornblendic bands are partially or wholly kaolinised and micacised plates of felspar, some polygonal, and then forming a very coarse or occasionally a fine-grained mosaic, others of granitic character. The felspar is generally much altered, and frequently the plates are roughly orientated in the direction of the hornblendic bands. Measurement of extinction angles was generally impossible, but in two cases the angles were those of andesine. Potash and other species, however, are probably also present. Many of both the quartz and felspar crystals are cracked, and in some, irregular extinction is observed. In some of the hornblende crystals pleochroic halos round sphene granules are visible. There are rare grains of epidote. The quartz is in irregular plates, but it is not so common as the felspar. An imperfect gneissose structure is shown in section.

The rock is a *gneissose hornblende felspar-quartz rock,* a gneissose quartz-diorite closely resembling the facies in Duff's Bore at 789 feet.

[**13997**] from G.M.L. 2688:—

This is a finely foliated, greyish-green, fine-grained rock with numerous needles of hornblende on the foliation surfaces. The rock is extremely friable.

There are in section, numerous plates of clear quartz, and felspar in tables and columns elongated more or less in the same direction, areas of coarsely granulitised quartz and felspar plates, and occasional rounded crystals of both felspar and quartz apparently untouched in the process of elongation. In this mass are irregular bands of small hornblende prisms all arranged more or less with their long axes parallel, some thick, some thin. The hornblende forms are usually in bands, but many of the smaller rods and grains are sporadically scattered. Interspersed with the bands are occasional flakes of brown biotite and a brownish chlorite perhaps in course of alteration to biotite. (Fig. 64.)

Fig. 64.

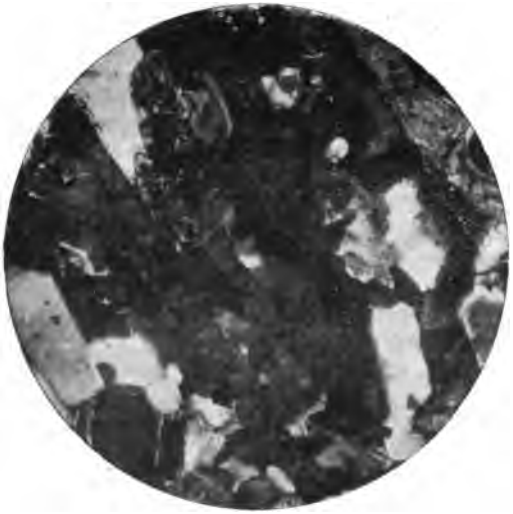

Photo: R. A. Farquharson. Neg. 1608.

[13997]: Granulitic hornblende-quartz-felspar gneiss, showing the structure.

There are cases in which the biotite is fairly evidently in course of formation from green chlorite, some plates being half biotite and half chlorite. Most of the felspar is fresh, but some larger plates are clouded by kaolin. There is, in general, little irregular extinction, and no cracks were observed in the crystals. The structure is more or less distinctly foliated.

The rock is a granulitic *hornblende-quartz-felspar gneiss.*

[13998] from G.M.L. 2688:—

This specimen is a dark-green, rather fine-grained, finely foliated hornblendic rock with needles of hornblende with parallel orientation on the foliation surface.

In structure and composition it is very similar to the previous specimens. There are numerous irregular grains and flakes of greenish hornblende in a mass composed in places of a granulitic mosaic of the same minerals. Occasional crystals of quartz and of felspar larger than usual also appear.

The rock is a foliated fine granular to granulitic *quartz-felspar amphibolite* verging on a granulitic hornblende gneiss.

[$\frac{1}{15}$] from bottom of Recovery Shaft, G.M.L. 2087:—

The rock is a medium-grained greyish-green dioritic rock with an indistinct foliation observable on some fractured surfaces. Green hornblende is apparently the chief mineral constituent.

In section, the rock is composed of imperfect interrupted bands of green hornblende in irregular plates, platy aggregates and ragged prisms, often with associated granular sphene and some brown-red biotitic flakes, separated by coarse polygonal plates of felspar clear or only slightly kaolinised. The felspar plates are frequently untwinned, but generally broadly lamellated when they are twinned, though suitable sections for determination of the species are not present. Rarely a much banding is noticeable in the large felspar plates. A striking feature of the slides is that quartz appears to be absent from them, even the clearest crystals proving to be felspar.

In sections, however, of another specimen from near the same locality, some large ragged plates of quartz are undoubtedly present, and these show cracks and irregular extinction.

Iron ores are not uncommon in ragged grains, and some calcite is present in some sections.

The structure most closely approaches a very coarse mosaic of which the elements are large polygonal plates of felspar and in which the hornblende forms occur.

The rock is an obscurely foliated, coarsely granulitic *hornblende-felspar amphibolite.* From the various sections it is evident that while some portions are devoid of quartz, others certainly contain it, and these latter are rather granulitic hornblende gneisses than amphibolites.

[$\frac{1}{16}$] from G.M.L. 2087:—

This is a fine-grained very dark grey, finely foliated rock with numerous black scales of biotite on the foliation surfaces.

In section there is a marked foliation shown by numerous grains, small ragged plates and prisms of green hornblende with numerous scales and flakes of brown-red biotite and biotitic chlorite associated with the hornblende as well as occurring separately, all arranged with their long axes parallel, and forming strings and thin bands separated and interrupted or punctuated by numerous small polygonal crystals of felspar, with quartz plates occurring in strings or veinlets. In places some much larger elongated quartz plates also occur in strings or bands, and some bands of coarse, slightly kaolinised felspar plates also occur. There is a considerable amount of pyritic ore. Many of the hornblende forms show a partial alteration to chlorite and then to brown biotitic flakes.

The structure is markedly granulitic and foliated.

The rock is *a biotite-hornblende gneiss.*

The sections forwarded by Mr. Blatchford include two from the No. 2 Bore, Edna May, Nos. 2857 and 2858. These prove to be fine-grained granulitic hornblende schists, with marked schistosity or incipient foliation. They consist of numerous long, thin rods or prisms of green hornblende, all with parallel alignment and frequently perforated, separated and interrupted by an equal number of grains and small plates of felspar, lenticular or in long, thin shapes, elongated parallel to the hornblende. Generally the felspar is fresh, but in places it is partially kaolinised. Quartz, if present, is but poorly developed. Some specimens are rather coarse-grained, with larger hornblende prisms and with rare altered fibrous reddish-brown flakes of biotitic character.

Another section, No. 2862, from near the Boarding-house, Duff's Lease, is very similar to the above, but more intensely hornblendic, with hornblende in small rods, plates, or grains with general parallel alignment, but with little of the felspar mosaic.

No. 2859, from G.M.L. 2688, is another very fine-grained granulitic amphibolite or hornblende-schist (according to the direction in which the section is cut), with a preponderance of small pale-green hornblende grains, perforated plates or prisms separated by small felspar grains and plates. (Fig. 65.)

Fig. 65.

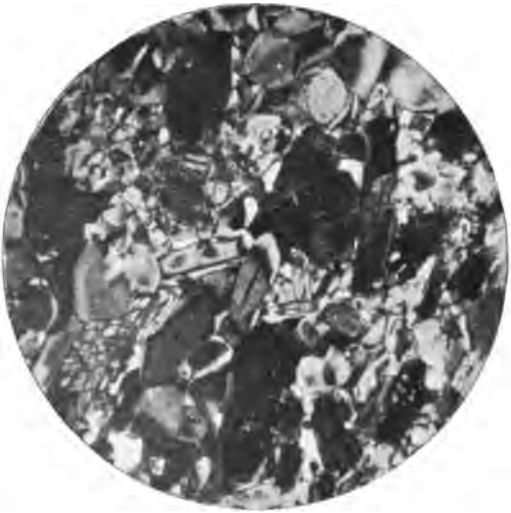

Photo: R. A. Farquharson. Neg. 1609.

Section 2859: The fine-grained granulitic hornblende schist, showing the structure.

No. 2860, from G.M.L. 2079, is rather similar to No. 2859, but the hornblende occurs almost to the exclusion of the colourless constituents. Moreover, it is not in rods or elongated prisms, but is platy or stumpy prismatic, and the individuals are much larger in size. The plates are separated by a very sparsely developed fine-grained felspar mosaic. Granular sphene is noticeable. This facies is a fine-grained, platy or prismatic amphibolite, though its structure may be foliated in a section cut in a different direction.

Finally, No. 2861, from G.M.L. 2088, is another granulitic hornblende schist or gneiss, with pale-yellowish-green hornblende much in excess of the clear, granular, felspar mosaic. Some rare reddish-brown biotitic scales occur with the hornblende.

(b.) Another virtual outcrop occurs in a shaft just outside the south-west corner of G.M.L. 2762. It is represented by two specimens [13999] and [$\frac{1}{23}$].

[13999]:—

This is a medium-grained, greyish black rock with imperfect foliation and with numerous small black prisms and rods of hornblende showing on the surface, mostly with parallel orientation. The cross fracture has a vitreous appearance.

The rock consists of a highly granulitic mass of small felspar and quartz plates of more or less polygonal shape, forming a mosaic in which are fairly numerous small grains and flakes of a yellowish-green hornblende, in places partially chloritised. Indistinct aggregates of yellow epidote are also present. The felspar is generally fresh and untwinned, but twinned plates occur. The structure is certainly granulitic, occasional large plates of quartz and felspar being visible that are almost wholly granulitised.

The rock is a granulitic *hornblende-felspar-quartz* rock, a granulitic hornblende gneiss with imperfect foliation.

[$\frac{1}{23}$], from the South-West corner of G.M.L. 2762, close to [13999]:—

This is a much weathered reddish, iron-stained rock markedly foliated with small imperfect bands of felspar, and with micaceous chloritic scales of a yellow colour on the foliation surfaces. The appearance of the rock at once suggests that it is a highly altered form of [13996].

In section, this suggestion is confirmed. Though decomposition is advanced and the slides are heavily iron-stained, imperfect bands of kaolinised felspar and subsidiary quartz plates are interspersed with yellowish-green and iron-stained ragged chloritic prisms that have been derived from the decomposition of hornblende prisms. The felspar and quartz form a coarse mosaic of polygonal plates. The chloritic forms are all in parallel alignment.

The rock is decomposed foliated *hornblendic gneiss,* originally similar to [13996].

(c.) An outcrop, or what is equivalent to an outcrop, occurs at the old townsite near the western margin of the granite outcrop on which the townsite stands. The rock is represented by [13390].

This is a distinctly foliated, variegated rock consisting of pale greenish-white bands and streaks, between which and through which are patches, bands and streaks of dark-green colour composed of parallel needles of hornblende.

The rock in section consists of bands or patches of polygonal plates of felspar with irregular plates and grains of colourless augite, and bands, patches or streaks of grains and prisms of green hornblende in dense aggregates with or without associated small plates of fresh or kaolinised felspar. There is a sensible parallel alignment of the hornblende forms, though many of them occur with a single set of cleavage traces at varying angles to the direction of alignment or banding. Sphene granules and calcite grains and plates occur in the pyroxene bands. The hornblende has evidently been derived from the pyroxene, since pyroxene plates partially altered to greenish hornblende are not uncommon. In some places the hornblendic bands are composed of small grains and rods of green hornblende associated with granular felspar, and these portions show a resemblance to the hornblende schist of the No. 2 Bore, Edna May, of which section 2858 is an example.

A noteworthy feature of the slides is that quartz appears to be quite absent, and this constitutes an additional resemblance to the No. 2 Bore, as well as a link with section 2860 and 2859 already described.

The rock is a variegated, partially foliated *pyroxene-hornblende-felspar gneiss* without quartz. Complete alteration of the pyroxene to the green hornblende would result in a fairly foliated hornblende schist.

(d) Outcrops of greenstone occur at Boodalin Soak as small islands in the granite. These are represented by the single specimen [½].

This is a rather fine-grained dark-green hornblendic rock. In section it consists of a loose mass of long thin ragged prisms of green hornblende in all orientations, sometimes in aggregates with ragged plates of hornblende, represented by a fine-grained mosaic of felspar plates in which remains of former columnar felspar crystals still remain, and in which are numerous grains, rods, and fragments of the green hornblende. The felspar is highly kaolinised, and quartz, if present, is only in very small quantity. Though no foliation was noticeable in the sections examined, other sections cut subsequently show a fine foliation with numerous parallel rods, needles and prisms of hornblende separated by fine-grained granular felspar mosaic in which many small grains of hornblende also occur. (Fig. 66.)

Fig. 66.

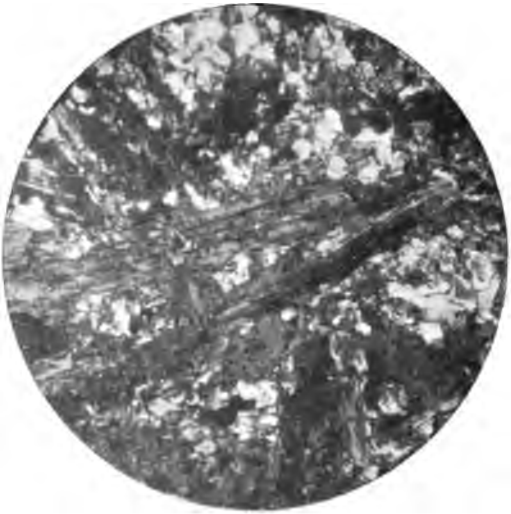

Photo: R. A. Farquharson. Neg. 1610.

[½] **The fine-grained, finely foliated epidiorite from Boodalin Soak.**

The rock, therefore, is a fine-grained, finely foliated *hornblende schist or epidiorite.*

(e) From the Lloyd George Lease two specimens were obtained, [13993] and [13994].

[13993]:

Is a fine-grained, dark grey-green, finely foliated hornblendic rock, with parallel needles of hornblende easily visible.

Sections consist of numerous small grains, prisms and plates of green hornblende with the interspaces occupied by grains of clear quartz and felspar, the latter often somewhat turbid, the former sometimes rather large. Marked foliation is noticeable in suitable sections. The structure is granular. In places the hornblende occurs in platy or prismatic aggregates.

The rock is a fine-grained, finely foliated *hornblende gneiss* or *granular felspar-quartz amphibolite.*

[13994]:

This is another finely foliated dark grey-green hornblendic rock with surfaces silky from minute needles of hornblende. Microscopically, the rock very closely resembles the sections from the No. 2 Bore, Edna May Lease. There are numerous more or less parallel small prisms, rods or grains of green hornblende, separated by small polygonal grains or plates of clear or partially kaolinised felspar forming a mosaic. Quartz, though carefully sought for, could not be identified.

The rock, therefore, is a finely foliated, fine-grained *prismatic* or *roddy hornblende schist.*

(f) A specimen was obtained, [$\frac{1}{745}$], which represents the country rock of the Battler Mine, G.M.L. 2769. This is a very fine-grained, dark grey, minutely schistose or foliated acicular hornblendic rock, with patches that show a pinkish tinge.

In section, the rock is a fine-grained granulitic mass of small grains, rods and prisms of yellowish-green hornblende with their long axes arranged more or less parallel but not in definite folia, and with the interspaces between the rods and grains occupied by small grains or plates of clear felspar and occasional quartz grains. In places the felspar is slightly kaolinised, in places zoisitised. The pinkish tinge is due to a development of a reddish brown biotitic chlorite which occasionally passes into biotite. A small quartzo-felspathic band with granular zoisite traverses the rock parallel to the direction of foliation. The appearance of the slides resembles to some extent that of the hornblendic patches of [13990] from the Townsite.

The rock is a schistose or foliated granulitic *hornblende-felspar rock* or *acicular hornblende schist* verging on a granulitic hornblende gneiss, and the pinkish tinge arises from brown biotite and brown biotitic chlorite flakes.

Other specimens from a section at the bottom of the shaft in the Battler Mine are represented by [$\frac{1}{1154}$].

This is a very fine-grained finely schistose or foliated roddy prismatic hornblende schist with pale green lenticles of diopside, a little calcite, green hornblende, and quartz. The hornblende schist consists of numerous parallel small rods and prisms of hornblende with occasional elongated scales of brown biotite and biotitic chlorite, separated by fine granular, slightly kaolinised felspar plates. Some quartz grains also occur with the felspar. The augite plates are in course of alteration to green hornblende. The sections are identical with those from 203 feet to 205 feet in the No. 3 Bore, Edna May. It is highly probable that the hornblende schist has been derived from a pyroxene-felspar rock by the breaking down and alteration of the augite to hornblende, and the granulitisation of the felspar was the result of dynamic stress. The coarser grained and more hornblendic specimens represent probably a facies of the original rock in which augite was predominant.

(g) In the Edna May Consolidated, white clayey rocks with reddish streaks occur. They are too decomposed to be sectioned, but they possess characters suggesting an origin of the rock from the tremolitic serpentinous facies to be described subsequently in connection with Duff's Bore, Edna May Mine.

(h) Finally, there is [$\frac{1}{1155}$] from one mile south of road Weston's to Boodalin.

This is a finely foliated dark-grey rock with white felspar "augen" of small size enclosed by wavy folia of biotite with intermixed felspar. There is much biotite in small scales on the foliation surfaces.

In section the rock is composed of patches of fine granulitic felspar and probably quartz mosaic enclosing large ragged partially granulitised and slightly kaolinised felspar plates, with small elongated patches of a mixture of coarse felspar and quartz plates, and numerous small and large scales of brown-yellow biotite in scattered scales, in strings and imperfect folia.

The rock is a foliated *biotite-felspar gneiss* with subsidiary quartz.

(2.) *The Bore Cores:*

(a) The No. 3 Bore Core, Edna May [$\frac{1}{42}$].

The specimens of this core, ranging from a depth of 179 feet to a depth of 251 feet, consist almost entirely of fine-grained granulitic hornblende schist, sometimes with, sometimes without reddish-brown biotite and chlorite.

The facies from the depths, 179 feet to 184 feet, 184 feet to 186 feet, 203 feet to 205 feet, 230 feet to 232 feet, and 241 feet to 243 feet, may be taken as typical of the core.

179 feet to 184 feet.—The rock is here a fine-grained granulitic hornblende schist with reddish-brown biotite and chlorite. The hornblende is in perforated plates and long thin needles and broader ragged prisms, and is associated with granular polygonal felspar plates frequently elongated parallel to the schistosity. The facies has the structure of a foliated hornblende gneiss, but quartz is either in extremely small amount or entirely absent. There is considerable resemblance between this rock and [13994] from the Lloyd George Lease.

184 feet to 186 feet.—Here the hornblende consists in part of the fine granular roddy prismatic type, and in part of the coarser ragged platy and prismatic type. With the latter is associated kaolinised and zoisitised felspar, and a quartz vein was observed. The two types, especially the latter, resemble the hornblendic bands in [13990] that have been derived from an original pyroxene-felspar facies.

203 feet to 205 feet.—The facies consists in part of a fine-grained finely foliated or schistose granulitic mass of felspar plates, hornblende grains and brown-red biotitic scales, in part of coarse augite (diopside) surrounded by ragged green hornblende prisms and gradually passing through these into a hornblende-felspar portion with micacised felspars, and through this into the fine granulitic phase. Some large quartz plates are associated with the proxene.

230 feet to 232 feet.—This portion consists of long thin needles of hornblende and small scales of brown-red biotite in a fine granulitic mass of felspar plates often elongated in the direction of foliation. There are a few large ragged plates of hornblende that have escaped the foliation.

241 feet to 243 feet.—This facies is coarser-grained than that at 230 feet to 232 feet, and is practically identical with that at 179 feet to 184 feet. (Fig. 67).

Fig. 67.

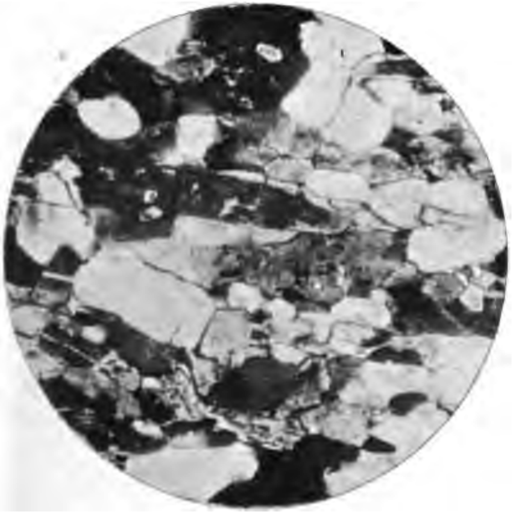

Photo: R. A. Farquharson. Neg. 1611.

[$\frac{1}{42}$] 241ft.-243ft. in No. 3 Bore, Edna May: The granulitic hornblende schist, showing the structure.

In this core, therefore, the rock is predominantly a granulitic hornblende schist since quartz, though present in some slides, is, as a rule, absent. In some cases, the structure is very fine-grained and roddy, in others coarser-grained and prismatic so far as the hornblende is concerned. Further, in most sections, though not in all, brown biotite and brown biotitic scales are common. There are points of resemblance between some of the sections and the hornblendic portions of [13990].

(b.) Duff's Bore, Edna May Mine [$\frac{1}{30}$].

From the samples* of the core of this Bore in the possession of the Geological Survey, the evidence afforded by the bore bearing on the nature of the country rock is as follows:—

From a depth of 180 feet, at which the samples began to be collected, and extending with slight variations to a depth of about 426 feet, the rock is a biotite granitic gneiss of which a description will be given subsequently. Between these limits, 180 feet to 426 feet, the only marked rock changes are small veins of white aplitic granite an at 364 feet the granulitic hornblende-biotite facies already discusse in the section on the Greenstone Dykes.

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*Which is not, however, continuous.

At 427 feet, however, there appears a complete change of countr The rock at this depth is an actinolitic chloritic hornblendite, co sisting of a plexus of acicular crystals and plates of pale-green nearl colourless hornblende with the interstices occupied by yellow-brow chlorite. (Fig. 68.) Except for the occurrence of granite veins, th hornblendite extends to a depth of 465 feet, the only variations i composition noticeable in it being the appearance of some brown-re biotitic flakes at 440 feet, and some calcite grains at 465 feet.

Fig. 68.

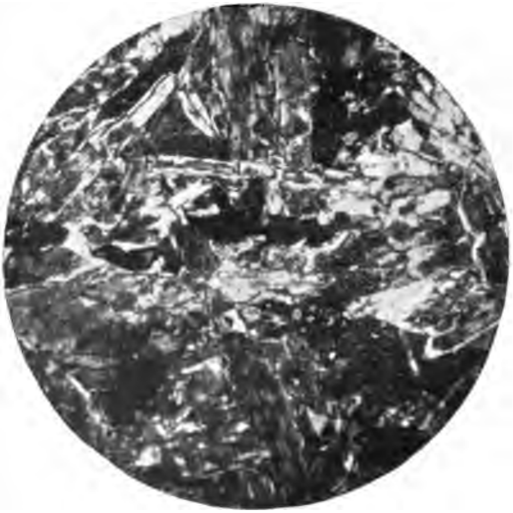

Photo: R. A. Farquharson. Neg. 1612.

[$\frac{1}{35}$] 427ft. in Duff's Bore, Edna May: The actinolitic hornblendite, showing the plexus of acicular crystals of hornblende in chlorite.

At 465 feet another change occurs. The rock at this depth is rather fine-grained, almost black, with numerous minute reflecting scales of a micaceous mineral and occasional dense black thin bands or streaks. Sections show a mixture of thin prisms and grains of colourless hornblende (tremolite); numerous ragged rectangular scales of a mineral that is very pale-pink in colour, pleochroic, brilliantly polarising, with the cleavage traces filled with strings of iron ore; numerous small brightly polarising grains exhibiting cracks and resembling olivine; more or less disintegrated colourless plates with cracks, in some cases like the cleavage of a pyroxene, in others like that of hornblende; many bleached, almost isotropic chlorite scales, and some small areas, almost isotropic, of serpentinous material. There is much granular iron ore scattered over the slide, especially along the cleavage traces of the colourless micaceous mineral. The tter very closely resembles colourless muscovite, but from the small t of potash or soda in the analysis, it must belong to the talc or rite species. (Fig. 69.)

Fig. 69.

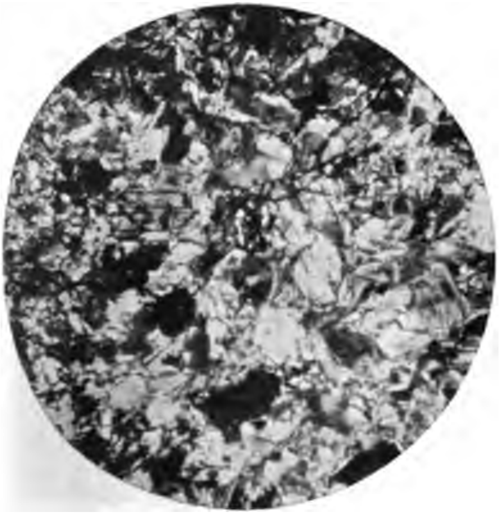

Photo: R. A. Farquharson. Neg. 1613.

[$\frac{1}{35}$] **466ft. in Duff's Bore: The tremolitic-serpentinous-chloritic facies, showing one variety of structure.**

The rock has no defined structure. It is a very basic tremolitic-ritic-serpentinous facies. An analysis of portion of it from the level [G.S.M. 1/39, G.S.L. 6403D] made in the Survey Laboragave these results:—

SiO_2	43·60
TiO_2	·27
CO_2	*Nil*
P_2O_5	·53
H_2O+	5·56
K_2O	·07
Na_2O	·22
CaO	4·69
MgO	33·24
MnO	·19
FeO	4·46
Fe_2O_3	3·49
Al_2O_3	3·46
Cr_2O_3	·16
FeS_2	·09
H_2O-	·16
Total	100·19

Analyst—H. Bowley.

The extremely basic and highly magnesian character of the rock is strikingly confirmed by this analysis. The percentage of chromium in the rock is noteworthy.

The 466 feet type extends to 498 feet, except for breaks of actinolite-chlorite rock at 472 feet, and of actinolitic hornblendite, with brown and green chlorite at 474 feet, and a band of it also occurs at 503 feet, 511 feet, and 516 feet.

From 516 feet to 520 feet, the acicular actinolitic hornblendite again makes its appearance with hornblende prisms as a plexus in chlorite, of which much is brown biotitic.

Again, from 527 feet to 549 feet the facies is mostly chloritic hornblendite, amphibolite or epidiorite. There is a break at 542 feet, which consists of imperfectly foliated, granulitic, chloritic biotite-quartz-felspar-hornblende rock that may have arisen as the result of heat and pressure metamorphism of a felspathic chloritised amphibolite. An analysis in the Survey Laboratory of a facies at 536 feet [G.S.M 1/39, G.S.L. 6404D] gave the following results:—

SiO_2	50·69
Al_2O_3	5·97
Fe_2O_3	2·31
FeO	8·04
MnO	·25
MgO	17·85
CaO	11·26
Na_2O	·32
K_2O	·38
H_2O-	·04
H_2O+	2·22
TiO_2	·35
CO_2	*Nil*
P_2O_5	·17
FeS_2	·09
Cr_2O_3	·39
Total	100·33

Analyst—H. Bowley.

At 550 feet there is an imperfectly foliated highly felspathic facies in places coarsely granulitic, with occasional flakes of green chlorit sometimes obviously changing into the reddish-yellow biotitic variety and in places with numerous flakes of brown-red biotitic chlorit and biotite that have fairly certainly been derived from pre-existin chlorite. Rarely a fragment of green hornblende occurs. By furthe change of the green chlorite, the rock would pass into a facies essentially the same as the granulitic granitic gneiss of 180 feet to 22 feet, though, as will be shown later, quartz is much more commo in the latter.

From 551 feet to 636 feet there are frequent variations of smal thickness, the chief facies being the chloritic hornblendite, an actinoliti amphibolite, a chloritic schist, and the tremolite serpentinous rock o 466 feet.

At 638 feet occurs a granulitic hornblende-felspar-quartz rock (hornblende-gneiss), passing into a facies with much brown biotitic chlorit mixed with hornblende and chlorite that is apparently in process o alteration to the brown mineral.

Then from 639 feet to 741 feet the rock varies from a fine-graine amphibolite to an actinolite-chlorite rock, or hornblendite, with portion resembling both granulitised and mosaic platy diorite. An analysis of a facies at 658 feet to 674 feet [G.S.M. 1/39, G.S.L. 6406D] gave the following results:—

SiO_2	51·46
Al_2O_3	11·43
Fe_2O_3	1·38
FeO	8·21
MnO	·30
MgO	12·33
CaO	10·83
Na_2O	1·40
K_2O	·58
H_2O-	·03
H_2O+	1·71
TiO_2	·58
CO_2	*Nil*
P_2O_5	·25
FeS_2	·03
Cr_2O_3	·08
V_2O_3	·04
Total	100·64

Analyst—H. Bowley.

At 741 feet there is a change from a granulitic chloritic amphibolite to a coarsely granulitic diorite or hornblende gneiss, but the two facies are doubtless genetically connected.

From 742 feet to 780 feet the rock is mostly of amphibolitic character, though a break occurs at 770 feet, which consists of quartz-felspar rock with numerous brown biotite and chlorite scales, flakes of greenish hornblende and possible fragments of original augite.

At 785 feet, and extending to 789 feet, the rock is a coarse-grained diorite or amphibolite with pyrrhotite and brown-red biotite and chlorite flakes. In places, especially at 789 feet, the facies is more or less distinctly foliated.

At 790 feet the rock changes to a fine-grained amphibolite or hornblende schist, then at 792 feet it is the facies of 789 feet, and from 792 feet to 794 feet the rock is a fine-grained amphibolite.

It will thus be seen that, so far as this Bore Core is concerned, the chief greenstone facies present, exclusive of the biotitic granitic gneiss, are:—

(a.) The actinolitic-chloritic hornblendite appearing first at 427 feet.

(b.) The tremolitic-chloritic serpentinous rock appearing first at 466 feet.

(c.) The amphibolite or diorite, more or less foliated, appearing chiefly towards the end of the bore, and particularly from 785 feet onwards.

(d.) Granulitic-hornblende-felspar-biotite rock at 364 feet. These closely resemble the granulitic portions of rocks such as [13990] and $\frac{1}{745}$ from the Battler Lease.

(e.) The Bore Core from Weston's Reward Mine:

The results of examinations of the portions of the core available are as follows:—

211 feet.—There are two facies, one a dark-green hornblendic facies, and the other a pale greenish brown.

The former is fine-grained platy epidiorite, the latter a highly biotitic and micacised portion of it.

277 feet.—A finely foliated hornblende-felspar rock which is gneissic in those portions where quartz is developed.

248 feet.—A granulitic prismatic hornblende-felspar rock. Since quartz is apparently absent, the rock is a foliated granulitic prismatic amphibolite.

312 feet.—Very similar to the facies at 248 feet, though a little quartz is occasionally present.

321 feet.—In places, the rock closely resembles the facies at 248 feet, but generally the hornblende has disappeared, and there is a fine granular or granulitic mixture of plates of felspar separated by small brown-red flakes of biotitic material.

The rock is in places a fine grained granulitic amphibolite or hornblende gneiss, but generally a granulitic biotitic-hornblende gneiss in which the biotitic flakes are present almost to the exclusion of the hornblende.

360 feet.—A foliated banded granulitic amphibolite or gneiss without quartz.

438 feet.—There are irregular parallel bands or strings of platy, granular and prismatic green hornblende separated frequently by large turbid platy and columnar crystals of felspar and quartz. In portions of the slide the hornblende is in large ragged plates, and the felspar is in flaky and columnar forms as in diorite, while ragged quartz plates occur in association with the felspar. The rock is in places foliated, in places platy; the structure at times granulitic, but generally plutonic.

The rock is, therefore, a coarse platy quartz-diorite, in places foliated and granulitised to a foliated hornblende schist, amphibolite or gneiss.

In brief, therefore, the core shows a fairly continuous series. All the core samples are strongly hornblendic and felspathic. Some have a slight, one a strong, development of the red-brown biotitic flakes, and a few show a certain amount of clear quartz.

All, therefore, are hornblendic-felspathic, and appear to have been derived from a rock of dioritic affinities.

(3.) *The Specimens from the Plat in the Shaft at 300ft. Level, Edna May Mine*:

These rocks were collected with the object of throwing additional light on the nature of the greenstone country. Owing to the circumstances under which they occurred, it was, according to the information supplied by Mr. Blatchford, impossible to make out their field relations to one another. The facies present, however, excluding specimens of doubtful origin, are:—

(a) The tremolitic serpentinous rock such as occurs at 466ft. in Duff's Bore.

(b) The prismatic hornblendite with biotitic varieties and occasionally with pyrrhotite.

(c) A finely foliated chloritic hornblende-quartz-felspar gneiss with much turbid felspar.

(d) A facies similar to the biotitic granitic gneiss of Duff's Bore.

(e) A schistose or foliated biotitic epidiorite or amphibolite.

(f) The chloritic actinolitic hornblendite very similar to (b).

3. Nature of the Country Greenstone Rocks and their Mutual Relations.

(1.) *The Nature of the Rocks*:

It will be gathered from the foregoing that the rocks in the vicinity of the lens of the Main Lode are:—

1. The foliated hornblende gneiss, occurring in a thin lenticular band or mass from the Junction Lease to the Western boundary of the Elsie Lease. The rock is in places quite coarse-grained and dioritic in appearance, in places quite fine-grained. While in some specimens felspar is equally developed with the hornblende, in others, hornblende is much in excess of the felspar.

2. The granulitic hornblende schist. This occurs in the Elsie Lease in shafts south of the point at which the hornblendic gneiss disappears (*see* Plan); it occurs at the south-west corner of G.M.L. 2679: it is found in shafts at the eastern margin of the Myrtle Lease: and it is predominant in No. 2 and No. 3 Bores, Edna May Mine.

Further, both the hornblendic gneiss and the granulitic hornblende schist occur in a shaft at the south-west corner of G.M.L. 2762, though specimens of the former are much decomposed.

Finally, a foliated fine-grained hornblende-gneiss or granular quartz-amphibolite and a fine-grained prismatic hornblende schist occur in the Lloyd George Lease.

3. A foliated pyroxene-hornblende-felspar rock occurring at the Townsite.

4. A foliated hornblende schist or epidiorite at Boodalin Soak. This is virtually identical with the granulitic hornblende schist.

5. An acicular hornblende-schist verging on a granulitic hornblende gneiss, and a fine-grained foliated prismatic or roddy hornblende schist with lenticles of pyroxene, found in the Battler Lease.

6. A foliated amphibolite or diorite occurring near the bottom of Duff's Bore at about 785ft., and a coarse platy diorite at 438ft. in the bore at Weston's Reward.

7. An actinolitic chloritic hornblendite occurring at the plat in the Edna May shaft, 300ft. level, and at a depth of 427 feet in Duff's Bore.

8. Finally, a tremolitic-serpentinous rock found at 466 feet and greater depths in Duff's Bore, also in the plat in the Edna May shaft, and, judging from weathered clayey specimens, in shafts near the western margin of G.M.L. 2617.

These facies are ultimately reducible to two groups:—

(a) The foliated felspar-hornblende rocks:

These include rocks with quartz such as the foliated hornblende gneisses or quartz-diorites, and those without quartz, or with it in only small amount, such as the granulitic hornblende schists and foliated epidiorite, and the foliated pyroxene hornblende schist.

(b) The non-felspathic hornblendic rocks:

Included amongst these are the actinolitic chloritic hornblendite and the tremolitic-serpentinous facies.

(2.) *The Mutual Relations of the Rocks*:

Owing to the impracticability of observing rock junctions, to the paucity and scattered nature of the exposures, nearly all of which are confined to shafts or to the mine workings, and to the absence, indeed, of any decisive field evidence, the mutual relations of the rocks are very difficult to make out.

The chief facies are undoubtedly the granulitic hornblende schist and the hornblende gneiss, and of these the former certainly appears to have the wider distribution, and is probably the chief member of the country. In this connection, the inliers of greenstone at Boodalin Soak must, from their occurrence, be regarded as representative of the country, and these, as has been shown, are foliated hornblende schists or epidiorites closely resembling in structure and composition the hornblende schists from No. 2 and No. 3 Bores, and the other exposures of this rock in the various shafts and on the dumps. Moreover, the foliated pyroxene-hornblende-felspar rock of the townsite, though apparently different from the hornblende schists, has been shown to consist of hornblendic portions microscopically very similar to the latter; and since it is plain in the slides that the hornblendic portions have been derived from the pyroxenic, there is little doubt that the hornblende schists have been derived ultimately from a rock very similar to this from the townsite, and that this pyroxene rock must be included, from the point of view of origin and affinities, with the hornblende schists.

The relationship of the hornblende gneiss, however, to these hornblende schists is by no means clear. It apparently occurs mostly as a band or strip more or less surrounded by the hornblende schists, and since some varieties of it differ from the latter only in the presence of a little quartz, while exhibiting the same appearance and structure, it might be regarded as a derivative of a more quartzose modification of the original of the schists. On the other hand, from the characters of [13996], and of the bore core from about 785ft. in Duff's Bore, it certainly appears to have been formerly a quartz-diorite, and, as such, may have been a more acid dioritic intrusion into the original pyroxene-felspar rock that subsequently gave rise to the hornblende schists. Though both the hornblende gneiss and the hornblende schist occur in a shaft at the south-west corner of G.M.L. 2762, and also in the Lloyd George Lease, no evidence is obtainable of their mutual relation, and the evidence afforded by the bore cores is inconclusive. For the present, therefore, their relation must remain doubtful.

In the case of the actinolitic hornblendite and the tremolitic-serpentinous facies, there is even less evidence of the relation of one to the other, or of either to the surrounding rocks. All that is known of the hornblendite is that it occurs in two places: (a) in Duff's Bore at 427ft., at which point there is a clean break between it and the granitic gneiss that extends off and on from 180ft. At about 466ft. it passes into the tremolite-serpentine rock. (b) In the plat in the shaft at the 300ft. level, Edna May mine. In this locality it occurs again in association with the tremolitic-serpentinous rock, but again the relations of the two rocks to each other and to the granitic gneiss are obscure. Whether they are ultrabasic dykes and only magmatic modifications one of the other, whether they are separate dykes of different age, or whether the hornblendite at least is a basic modification of the hornblende schists, these questions, owing to the lack of exposures and of evidence generally, cannot for the present but remain unsettled.*

4. THE GREY BIOTITE-GNEISS OF THE LENS OF THE MAIN LODE.

This rock, containing as it does the chief quartz lodes of the Edna May Group of Leases, is the most important as well as the most interesting in the Westonia Field. It is to be best investigated in Duff's Bore core, where it persists with only small breaks from a vertical depth of 180 feet to a depth of over 400 feet. Between these levels there are, of course, many variations, but it has been found that the chief characters of the rock are those represented by the specimens from 180ft., 211ft., 223ft., 230ft., and 245ft.

In hand-specimen characters the rock is greyish or black-and-white in colour, fine to medium grained, and generally with a noticeable foliation marked by streaks of bands of black mica. In some cases thin quartz veinlets are present running parallel to the foliation planes, and, less commonly, there are water-clear quartz plates. In some varieties, particularly at 217 feet, the rock is strongly foliated, with pronounced quartz veins separated by quartzo-felspathic material with associated biotite scales and parallel to the foliation planes. On the latter, biotite scales are very common, flat parallel to the banding, and often associated with a considerable development of pyrites. At times, allowing for the difference in tint produced in rocks by hornblende on the one hand and biotite on the other, the specimens of this gneiss on the cross fracture show considerable resemblance in external characters to the more felspathic of the fine-grained hornblende-gneiss.

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* Since this was written, the writer has obtained sections which afford evidence that the hornblendic dykes and the tremolitic-serpentinous rock are merely variations of one another or of the same rock mass.

The microscopic characters of the rock may be gathered from the following descriptions of the typical samples:—

180 feet.—There is a mass of small variously shaped plates of slightly kaolinised, in places slightly micacised felspar, with associated small quartz plates fewer in number than the felspar, enclosing large lenticular as well as ragged rounded plates of quartz. The lenticles are often so drawn out as to appear as strings, and occur overlapping one another or *en échelon*. Further, distributed through the slide are individual flakes and strings of flakes of brown-red biotite, all arranged parallel to the foliation and sometimes forming indistinct bands. The foliation is clearly seen, being marked by the long thin lenticles, the tendency to parallel arrangement and drawing out of the smaller felspar and quartz plates, and by the arrangement of the biotite flakes. The quartz forms sometimes show irregular extinction. Amongst the felspathic platy mass are also some green scales of chlorite. (Fig. 70.)

Fig. 70.

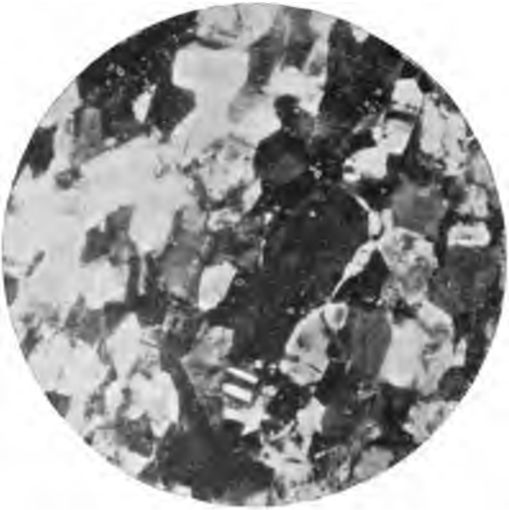

Photo: R. A. Farquharson. Neg. 1614.

[$\frac{1}{30}$] 180ft. in Duff's Bore: The biotitic granitic gneiss, or foliated biotite gneiss, showing the structure.

211 feet.—The core here is rather similar in section to that at 180 feet, but the foliation is even more pronounced. There are slightly kaolinised platy felspathic bands usually with associated small grains of clear quartz, represented by elongated plates of quartz, and sometimes by quartz veinlets which traverse the whole length of the slide. The felspar is frequently in ragged plates, most of which are elongated parallel to the foliation. In consequence, certain portions of the

slides have a fine granular structure, others a coarse elongated platy structure. Biotite again occurs in loose strings of long flakes of varying size, all elongated parallel to the foliation direction. Occasional grains of sphene, epidote and calcite, and small scales of muscovite in the felspar may be noticed, and small scales of green chlorite are in association with the biotite. The quartz plates often show cracks and uneven extinction.

The amount of biotite present is small, and the highly felspathic and quartzose character of the rock as well as the structure resemble those of foliated biotite granites. As in 180 feet, the absence of suitable sections renders the determination of the species of felspar present very difficult. There are occasional broadly lamellated plates, but generally twinning is absent. Observations by Becke's method indicate that most of the felspar has a refractive index lower than that of quartz and, consequently, that the felspar is largely between albite and andesine. Doubtless more than one species is present.

223 feet.—In sections from this depth there is a greater development of biotitic scales and of green chlorite scales, while there are undoubted small fragments of green hornblende in process of alteration to chlorite and to the brown biotitic mineral. Associated with the chloritic, biotitic and hornblendic flakes are frequently grains of sphene. The structure of the rock is rather finer-grained than in the other varieties, large portions consisting of a granular mixture of quartz and kaolinised felspar plates, some rounded, some rectangular or polygonal and most of them elongated parallel to the foliation. In the granular mass occur large lenticular plates of quartz similarly elongated parallel to the foliation, and rarer large irregular plates of kaolinised felspar. In almost all cases, the quartz lenticles are surrounded by the granular quartz and felspar mass, a fact which shows, in the absence of cracks, that much of the quartz, at any rate, is probably primary, *i.e.*, that it solidified with the other original minerals of the rock, and is not due to subsequent introduction of silica along the lines of foliation or along cracks. The fact that, while in many cases the coloured mineral in contact with the quartz plates is biotite, there are not uncommon instances in which it is green hornblende, further supports this conclusion. The hornblende grains and plates are, like the biotite flakes, in imperfect strings. (Fig. 71.)

230 feet.—The facies here is highly felspathic, with pronounced quartz veins, and with quartz grains associated with the felspar plates. A little vermicular intergrowth was observed. Sphene granules were quite common, usually associated with the biotite or green chlorite flakes.

245 feet.—The remarkable feature of the slides from this depth is that, while the quartz-felspar mass has in general the same characters as in the previously described sections, green hornblende is the chief ferro-magnesian constituent. There is a comparatively large development of it in plates and grains arranged in indistinct bands or strings with associated sphene granules. The quartz plates are generally ragged but elongated parallel to the foliation, and the felspars are similarly arranged. In portions of the slide, brown-red biotite scales are associated with the hornblende, and there may be seen alteration of the green hornblende to green chlorite, and from the green chlorite a gradual passage into the brown-red mineral. In other portions of the slide, the brown-red biotite with or without green or green-and-brown chlorite occur to the exclusion of the hornblende, and the rock then takes on the appearance as well as the structure of the 180 feet variety. (Fig. 72.)

There is undoubtedly a resemblance between the hornblendic portions of the slide and the sections of [13996] from the hornblendic gneiss. In the latter, however, the quartz is quite subsidiary to th felspar, and the latter is much kaolinised. In the sections of 24 feet, the felspar plates are often in polygonal or rectangular forn just as those minerals are in the finer varieties of the hornblendi gneiss, and sphene grains are equally common in both facies. Th major differences between 245 feet and [13996] are the finer grai of the former, the larger amount of quartz in 245 feet, the kaolinisa tion of the felspar in [13996], and the more fibrous structure an more decided banding of the hornblende in [13996].

Fig. 71.

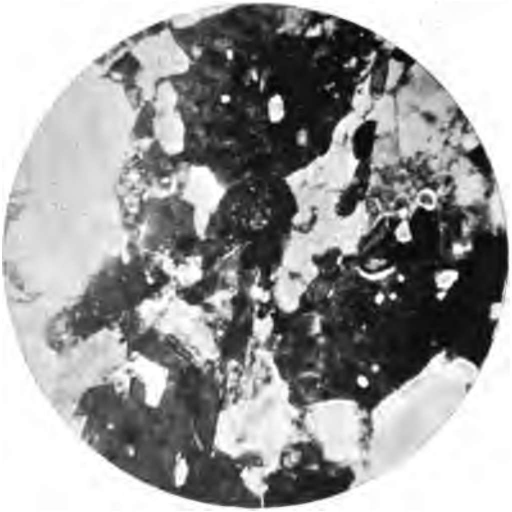

Photo: R. A. Farquharson. Neg. 1615.

[$\frac{1}{39}$] 223ft. in Duff's Bore: A facies of the gneissic rock with both biotite and a little hornblende.

It is clear, therefore, that at certain points, as at 180 feet, the rock has characters which ally it with foliated biotite granites or rather with foliated biotite gneisses, while at others, such as 223 feet and 245 feet, the biotite is associated with green chlorite and with green hornblende. Both at 223 feet and at 245 feet there is a noticeable passage of the green chlorite into brown-red biotite, and of the green hornblende into green chlorite. Particularly at 245 feet green hornblende is in places present to the exclusion of the biotite; in other places green chlorite is to be seen passing into brown biotite; and in others green chlorite is almost absent, brown biotite alone is present (with a few scales of green chlorite), and the mineral, associated as it is with felspar and quartz, gives an appearance to the slide in composition and structure closely similar to those of the 180 feet variety. Moreover, in the biotitic variety of [illegible] feet, again in the chloritic hornblendic variety at 223 feet, and

Fig. 72.

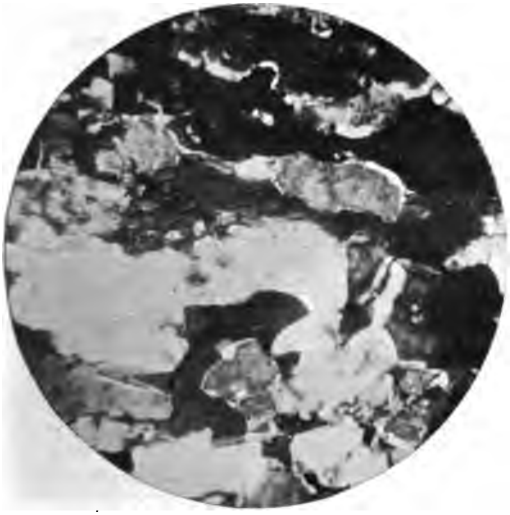

Photo: R. A. Farquharson. Neg. 1616.

[$\frac{1}{35}$] 245ft. in Duff's Bore: The hornblendic facies of the gneiss, with hornblende more prevalent than biotite.

in the very hornblendic variety at 245 feet, granular sphene constantly occurs, and it is always in association with the chlorite, the biotite or the hornblende, or with all of them. Further, the structure and composition of the 245 feet variety closely resembles those of [13996] except that in the latter quartz is less prominent and felspar predominant, the felspar is highly altered (kaolinised chiefly), and the hornblende is in places more or less fibrous. The structure or mutual relations, too, of the hornblende, quartz and felspar at 245 feet are very similar to those of the same minerals in hornblende-gneisses, and particularly in some of the finer-grained varieties of the hornblende gneiss of the area. There is the polygonal or elongated rectangular structure of the felspar, the indistinct banded arrangement of the hornblende, the lenticular form of much of the larger quartz plates, and the rectangular or linear forms of the smaller quartz plates. Sphene is also common both to the 245 feet variety and to the hornblendic gneiss.

On the other hand, the amount of quartz in the biotitic gneiss is greater than that in the hornblendic gneiss, and the large amount

of quartz in the former gives it a granitic character. It is pla
however, that much of the quartz occurs as thin veinlets parallel
the foliation, and the suggestion arises that part of the quartz
been intruded from the quartz lodes along the line of foliation
the gneiss by a sort of *lit par lit* injection. Nevertheless, there
be no doubt that the quartz occurring in plates in intimate asso
tion with the kaolinised felspar is original or primary.

The gneiss, therefore, is on the one hand, as at 180ft., a folia
quartz-felspar biotite gneiss, with resemblance to a granitic gne
on the other, as at 223ft., and particularly at 245ft., a ***hornblen***
quartz-felspar-biotite gneiss.

Origin of the Rock.

From the occurrence of the gneiss as shown on the plan, Pl
IX., it appears to be an intrusive dyke of lens shape. Certai
according to the field evidence, there is a clear break between it
the hornblendite at 426ft., so that where its junction with the co
try is observable, it appears to be well marked off by definite wa

On the other hand, it must be carefully noted that the only cl
junction observable is that with the hornblendite, which is it
probably intrusive. In no case could a definite junction be obser
with the hornblende-gneiss or with the foliated hornblende schi
Moreover, much attention must be paid to the resemblances betw
the hornblendic varieties of the rock, *e.g.,* at 223ft. and 245ft., and
finer-grained varieties of the hornblende gneiss and [**13996**]. In t
connection, the difference in the amount of quartz in the two fa
is a difficulty, and though this may, to some extent, be accounted
by injection of quartz from the quartz lodes along the planes
foliation, it appears that the rock was primarily more acid than
hornblendic gneiss. The 245ft. variety has affinities, both in co
position and structure, with a foliated hornblende granite, and
was for a time considered that the lens of the Main Lode might
an altered form of a hornblende-granite intrusion. The fact, h
ever, that no hornblende-granite at all comparable to this r
occurs anywhere except at great distances from the Edna M
group of leases rather discounts this view. Further, at the bott
of the Recovery Shaft two specimens were obtained, one,
medium-grained hornblendic gneiss, and the other from the imm
diate vicinity of a quartz vein, a fine-grained finely-foliated bio
gneiss [$\frac{1}{18}$], which has already been described. The only feasi
explanation of the occurrence of this biotite gneiss [$\frac{1}{18}$] appears
be that it is a facies of the finer-grained hornblende gneiss ther
dynamically altered by the introduction and contact action of
auriferous quartz reef. This biotite gneiss shows close similar
with the Edna May gneiss.

An analysis of the rock from 223 feet in Duff's Bore, made in the Geological Survey Laboratory, gave the following results:—

	I.	II.	III.	IV.	V.	VI.
SiO_2 ...	68·61	69·22	67·45	63·62	74·98	75·83
Al_2O_3 ...	14·24	14·29	15·51	14·38	12·85	14·11
Fe_2O_3 ...	·71	2·12	1·76	3·29	·16	·49
FeO ...	2·23	2·33	2·21	3·47	1·59	·12
MnO ...	·10	...	...	·28	·11	...
MgO ...	1·41	1·27	1·10	3·13	·59	·25
CaO ...	3·20	3·16	3·60	5·43	1·55	·55
K_2O ...	3·04	3·52	3·66	1·20	3·34	5·32
Na_2O ...	3·70	3·29	3·47	4·40	3·80	3·12
H_2O- ...	·06	...	·14	·22	·10	·13
H_2O+ ...	·30	·69	·63	·06	·48	·41
TiO_2 ...	·50	·36	·58	·72	·21	·08
CO_2 ...	·37	...	...	...	·05	...
P_2O_5 ...	·19	...	·12	...	·06	·20
FeS_2 ...	·11	...	...	...	·09	...
Fe_7S_8 ...	1·24	...	...	...	...	...
Total ...	100·01*	100·35	100·23	100·20†	99·96*	100·61‡

* Analyst H. Bowley. † Analyst E. S. Simpson. ‡ Analyst A. J. Robertson.

I. Rock at 223 feet. Duff's Bore.
II. Tonalite. Lana bei Meran, cited by Rosenbusch: Elem. der Gesteinslehre 1910, p. 166.
III. Granodiorite: Silver Lake Hotel, Eldorado Co., California, cited by Osann: Beiträge zur Chem. Petrog. 1905. p. 50.
IV. Granodiorite: Agamemnon G.M., Cue, Bull. 14, G.S.W.A.
V. Granite from Cosmopolitan Mine, Kookynie, W.A.
VI. Southern Cross Granite: Bull. G.S.W.A. No. 49, p. 57.
II., III., IV., V., and VI. are analyses of various rocks of granitic or quartz-dioritic character cited for comparison.

The rock at 223 feet was chosen for analysis, partly because it is intermediate in mineral composition between the highly biotitic facies at 180 feet and the predominantly hornblendic facies at 245 feet, and partly because of the comparative absence from it of quartz veinlets. The mode of the rock proves to be:—

Quartz, biotite, albite, orthoclase, quartz, hornblende, calcite, kaolin, chlorite, sphene, epidote, plagioclase.

Attempts have been made to calculate the actual percentage mineral composition, but these, on account of the presence of biotite, chlorite, and hornblende, the relation between the chlorite and the biotite, and the doubt as to the actual chemical composition of the biotite, chlorite, and hornblende, are unsatisfactory. Moreover, the results in any case are of little value so far as the origin of the rock is concerned, since both the mineral and chemical composition vary from point to point from 180 feet to 370 feet, and the analysis, except as regards the relative proportion of the alkalies and possibly the percentage of alumina, can scarcely be regarded as an accurate basis for the reconstitution of the mineral composition of the rock. Several analyses are really required from different portions of the biotitic gneiss, or perhaps even better, numerous sections and calculations of the composition by the Rosiwal method, but exigencies of time, labour, and apparatus preclude the preparation of these.

Nevertheless, considerable information may be gathered from the comparison of the analyses cited. In the first place, it is evident that the rock at 223 feet is more basic in composition than either the biotite-microcline granite at the Cosmopolitan Mine, or the biotite granite at Southern Cross. Both of the latter are true granites, and neither contains in any portion of its mass any hornblende. Consequently, as both are unsheared, it is unlikely that the biotite-gneiss of the Edna May is a sheared or foliated derivative of either of these.

Again, there are differences between the rock at 223 feet and that from the Agamemnon Mine at Cue. The latter, with 63.6 per cent. of silica, 1.2 per cent. of potash, and 4.4 per cent. of soda, is a basic granodiorite, *i.e.*, a type of quartz-diorite with subordinate potash-felspar, regarded by Lindgren as intermediate between a true quartz-diorite and a quartz-monzonite. The 223 feet type differs from it in the amount of silica, and especially in the relative proportions of the alkalies in the two rocks, and the differences are at first sight sufficient to indicate a fundamental dissimilarity between the 223 feet type and the granodiorite type. If, however, as appears probable, some of the quartz in the 223 feet type has been introduced as quartz veinlets, the normal rock, being necessarily less acid, would not differ decisively in silica content from the Cue rock. Moreover, not all granodiorites show the relative amount of the alkalies present in the Cue rock. The granodiorite from Silver Lake Hotel, California, exhibits alkali percentages very closely agreeing with those of the 223 feet type, and there is indeed a close correspondence between the analyses of the two rocks. Consequently, while the 223 feet type shows important differences from the Cue rock, the relation between it and granodiorites from typical localities is a close one.

Finally, a comparison of the analyses of the 223 feet type and the tonalite cited by Rosenbusch shows a surprisingly close correspondence between them, a correspondence which almost amounts to an identity. The tonalite of vom Rath is an acid quartz-mica diorite, classed by some petrologists with the hornblende-granites, but is characterised by a certain amount of andesine felspar. Structurally, the 223 feet type differs from the dioritic, and, though andesine may be present in it, none was determinable. In any case, however, the 223 feet type appears from the analysis to be a granulitic rock with a chemical composition not markedly dissimilar from an acid quartz-mica-diorite of the tonalite type.

On the evidence at present available, therefore, the gneiss is either (a.) a more acid quartz-diorite band or lens that is a differentiation of the original of the finer-grained hornblende-gneiss; or (b.) a more acid quartz-diorite or granodiorite intrusion that has been subsequently foliated and intruded by the auriferous quartz veins, and in which the original hornblende has been largely changed to biotite by dynamic stress and heat. From the close resemblance (in the analyses) of the 223 feet type to typical granodiorites, and the acknowledged close affinities of quartz-diorites of the tonalite type to granites, the rock is probably best recognised shortly as originally a granodiorite. As no clear junctions can be found showing the relation of the gneiss to the hornblende gneiss or to the granulitic hornblende schist, it is not at present possible to come to any definite conclusion, though it is most probably an intrusion.

5.—The Quartz Specimens.

Several specimens of the ore-bearing quartz from the gneissic granite lens of the Edna May, Edna May Deeps, and Edna May Central Mines were collected with a view to the microscopic determination of the origin of the quartz. The results of the examination of several slides are as follows:—

[$\frac{1}{780}$A]. From 150ft. Level, Edna May.

The specimen consists of sugary white quartz, much cracked.

In sections, there are large interlocking plates of quartz, some with uneven extinction and cracks, and all characterised by rows or thin lines of fluid pores often in aggregations. Felspar was not seen in the slides, but a small patch of a micaceous aggregate may represent it.

[$\frac{1}{780}$]. From back of No. 1 Stope, 225ft. Level, Edna May Mine.

The specimen consists largely of quartz similar in appearance to the above, apparently somewhat sheared, with grains of pyrites and occasional flakes of biotitic chloritic character.

In section there are again large interlocking plates of quartz, cracked, and with rows or lines of fluid pores often in aggregations. Associated with the quartz, however, are large more or less euhedral crystals of felspar apparently of two species, microcline and another acid plagioclase with albite twinning. Both species are considerably kaolinised, but the latter more so than the former. In some cases, the felspar plates occur at the junction of several quartz plates, in others they form a small veinlet; in others again, isolated plates occur surrounded by quartz. The microcline plates are generally irregular in outline, but the other plagioclase has generally at least one crystallographic boundary, and apparently crystallised before the microcline. In one instance at least, a small crystal of felspar without twinning was observed enclosed in a quartz plate. In places the felspars are micacised.

The quartz, therefore, associated as it is with felspar which occurs not undeniably in veins, is of granitic origin, and must be regarded as an acid portion of a pegmatitic facies, *i.e.*, of a quartz-felspar pegmatite in which the felspar is poorly developed.

[$\frac{1}{781}$A]. From 480 feet Level, Edna May Deeps.

This is of darker colour, apparently sheared or shivered, and with obscure bands in which a pale greenish-white felspar is prominently associated with the quartz, forming a pegmatitic variety. Away from these bands felspar appears to fail, but through the quartz mass thin veinlets of the felspar are seen to pass, and the intervening quartz appears devoid of felspar.

In section the quartz has the same character as in the other specimens. There are kaolinised felspar plates as before, but not only are there felspar inclusions in the quartz, but in some cases quartz inclusions in the felspar, facts which indicate a contemporaneous solidification of the quartz and felspar. The felspathic portions of the slides are of granitic character. Uneven extinction is common in the quartz and occasional in the felspar.

From the presence of the veinlets or bands of felspar in the specimen, two possibilities arise: (1) that these veinlets are felspathic segregation veinlets in a pegmatite; or (2) that they have been introduced subsequent to the formation of the quartz and along cracks in it. The occurrence of the reciprocal inclusions and the granitic character or structure of the rock, point to the former being the true explanation of their origin.

Another specimen of [$\frac{1}{760}$], shows not only the former characters in the quartz, but also very small but undeniable crystals of kaolinised felspar enclosed in the quartz.

Slides of some of the specimens show very large plates of quartz and finely lamellated felspar with distinct cases of kaolinised felspar enclosed in quartz, and of quartz enclosed in felspar. Some portions of these slides are finer in grain than the remainder and show associated biotite scales, one of which exhibit a distinct corrugation.

[$\frac{1}{758}$A]. From back of No. 1 Stope, 225ft. Level, Edna May Mine.

These are two specimens very similar.

One consists of water-clear quartz with a well-marked vein composed of pale-greenish felspar and quartz and yellowish felspar occurring generally in the margin of the veinlet. This yellow felspar is largely a kaolinised variety of the pale-green. There is a branch veinlet. It is noteworthy that while on one side of the specimen, the veinlets are clearly defined, on the other they broaden out, more of quartz is present and the specimen takes on a quartz-felspar pegmatitic appearance. Moreover, in places small patches of the pale-green felspar occur scattered amongst the water-clear quartz giving an even more nearly normal pegmatitic appearance to the rock.

In the other specimen the veinlets are not defined, the felspar being scattered through it in small patches both pale-green and yellowish in colour.

In section the veinlets consist of large plates of quartz with long strips of felspar that is an intergrowth of microcline and albite, generally highly kaolinised. Some of the strips are very narrow and resemble veinlets of felspar introduced along cracks. Undeniably, however, in places occur small areas of quartz surrounded by felspar and *vice versa*, and though, in some cases, the felspar appears to be connected up with a larger mass along cracks in the quartz, in others, the plates are isolated.

Another section is a very coarse platy mass of quartz and felspar (microcline-albite, extremely kaolinised).

The question arises as to whether the quartz-felspar veinlets are merely segregations or differentiation veinlets, or whether they are later veinlets introduced along cracks. Consideration of the quartz of the veinlets shows it to be identical with the surrounding quartz. Moreover, the mutual relations of the quartz and felspar, as illustrated by the inclusions, point to contemporaneous solidification. Further, the microcline of the veinlets occurs disseminated through the bulk of the quartz just as in other microcline-quartz-pegmatites;

and it is quite common to find highly quartzose and highly felspathic pegmatitic veins in acid granites, which, though appearing as intruded dykes or veins, are nevertheless virtually contemporaneous with the granites. For these reasons the veinlets are to be regarded as felspathic segregations or bands in granitic pegmatitic quartz, and not as distinctly later intrusions of microcline-albite felspar.

Examination of the quartz specimens therefore shows:—

(a.) that the quartz is a granitic quartz with rows of fluid inclusions;

(b.) that in most cases more or less felspar is associated with the quartz plates;

(c.) that, frequently, quartz plates are enclosed in felspar, and in the same sections felspar plates are enclosed in quartz; and that, consequently, the quartz and felspar have most probably solidified at or about the same time;

(d.) that the quartz itself is the solidified acid residuum of a quartz-felspar pegmatite.

Relation of the Quartz-Pegmatite to the Gneissic Granite.

The relation of the ore-bearing quartz specimens to the gneissic granite is of some interest and importance. There are two possible relations: (1) that they are merely quartz-pegmatite and quartz-felspar-pegmatite facies of the gneissic granite itself, (2) that they are quartz-pegmatite intrusions into the gneissic granite and consequently of later age. Some specimens of the quartz certainly appear to show transition stages from the gneissic granite. On the other hand, the maps indicate that the ore-bearing quartzes occur as veins or dykes, since, at their widest they cut across the foliation of their country rock and taper out into thin veinlets as they gradually become parallel to the foliation. Moreover, according to the field evidence, the ore-bearing quartz veins at depth frequently show a very well-marked line of demarcation from the gneiss with which they are in contact.

From the evidence available, therefore, they must be regarded as intrusions into the gneiss along cracks or fissures caused by dynamic strain, and consequently of later origin.

Associated with the quartz veins are frequent occurrences of wolfram and wulfenite.

6. THE GRANITES.

The specimens of these collected are easily divisible on external characters into two groups:—

(a) The comparatively fine-grained yellow granites.

(b) The comparatively coarse-grained grey or white granites.

(a) *The Yellow Granites:*

Typical examples of these are [$\frac{1}{3}$], [$\frac{1}{1162}$], and [$\frac{1}{1163}$]. They are all fine to medium grained, of a yellowish colour, and consist of crystals of quartz and felspar of equal size, with black flakes of biotite. In the two former, biotite is more common than in [$\frac{1}{1163}$] in which only scattered flakes occur. The characters of the rocks in section are represented by [$\frac{1}{3}$] and [$\frac{1}{1163}$].

A remarkable feature of [$\frac{1}{1163}$] is the presence of small particles of gold enclosed in the microcline felspar (Fig. 73).

Fig. 73.

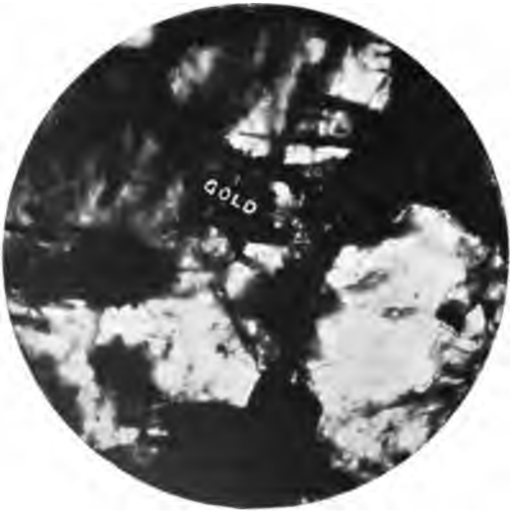

Photo: R. A. Farquharson. Neg. 1617.

[$\frac{1}{1163}$] Yellowish microcline biotite granite with gold in the microcline.

[$\frac{1}{3}$.] From 6½ M.P., Boodalin Road, Weston's.

The slides show tabular and somewhat irregular flaky crystals of felspar and irregular plates of quartz with occasional flakes of brownish biotite. The felspar is largely microcline, but occasional plates of a plagioclase with broad albite lamellation also occur. All the felspars are more or less kaolinised, and some are slightly micaceous. Intergrowths of felspar and quartz—some with an approach to graphic structure—are common, and small areas of vermicular pegmatite are observable. Round quartz grains also occur in the microcline. The structure is essentially granitic.

The rock is a yellow *microcline-biotite granite.*

[$\frac{1}{1162}$.] From Quarry at back of Old Townsite.
Is identical with [$\frac{1}{3}$].

[$\frac{1}{1163}$.] From Recovery G.M., Westonia.

Sections show the rock to be again a microcline-biotite granite very similar in structure and composition to [$\frac{1}{3}$], but with less biotite. Microcline felspar is predominant. There are again inclusions or intergrowths of quartz in microcline, and small areas of the vermicular micro-pegmatite are also present.

A remarkable feature of the rock is the presence of gold in the felspar. The gold is in the microcline in small particles with a kind of cellular structure, *i.e.*, the particles are very ragged in outline with small open spaces in the interior. In spite of the ragged character, however, it is difficult to see, since the gold undoubtedly occurs in association with only partially kaolinised felspar, how it can be secondary. Jacquet* has recorded the occurrence of free gold in microcline in a quartz-microcline rock from New South Wales, and there is at present no reason for believing that the occurrence in [$\frac{1}{1163}$] is anything but primary.

All three specimens, [$\frac{1}{3}$], [$\frac{1}{1162}$], and [$\frac{1}{1163}$], show both in external appearance and in composition and structure a marked similarity with the granite from Southern Cross described in *Bulletin* 49.

[$\frac{1}{781}$.] A specimen, [$\frac{1}{781}$], from Weston's Reward, 75 feet level, which occurs as a dyke, is included here.

A coarse-grained grey granitic rock composed of rather dark, sometimes nearly black, water-clear quartz crystals, mostly of rounded shape. in a mass of whitish felspar plates and some black scales of biotite. There are small segregations of biotite.

In section, there are large, somewhat rounded crystals of clear quartz and large irregular plates of partially kaolinised microcline, and of a plagioclase of acid species with albite twinning. There are also occasional flakes of brown biotite. A peculiarity of the rock is that the microcline often appears squeezed in between the quartz, indicating that the quartz has consolidated first. There are cracks in the quartz and some bending of the lamellae of the felspar, as well as uneven extinction. No intergrowths were observed, but there are inclusions of felspar in felspar and of biotite in felspar.

The rock is coarse *microcline-biotite granite.*

(b) *The Grey or White Granites*:

These differ from the yellow granites not only in colour, but also in being markedly coarser in grain and in being in places almost porphyritic, with large crystal plates of a white, pale-greenish white or faint pink tint.

The microscopic characters of the group are illustrated in specimens [$\frac{1}{740}$], [$\frac{1}{737}$], and [$\frac{1}{738}$].

[$\frac{1}{740}$]. From Ennuin Tank.

This is a very coarse-grained grey granitic rock with occasional large semi-porphyritic felspar crystals and scales and books of biotite.

In section there are very large platy and tabular crystals of partially kaolinised and partially micacised microcline felspar, and less common plates of a plagioclase with albite twinning, with aggregations of irregular plates of quartz and occasional flakes of brown biotite, in places chloritic. Wedge-shaped crystals of sphene also occur, sometimes of considerable size. Some vermicular intergrowth appears in places and an approach to zonary banding is noticeable in some of the felspar plates. Some of the most kaolinised felspars are quite turbid and enclose small grains of epidote. A few grains of black iron ore (ilmenite) appear sporadically.

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* Memoirs, Geol. Surv., N.S.W., 1894.

The rock is a very coarse-grained *semi-porphyritic microcline-biotite granite.*

[$\frac{1}{737}$]. From two miles east of 128 M.P., Rabbit-Proof Fence, South Yilgarn.

A medium-grained grey granitic rock with large semi-porphyritic pinkish felspar crystals in a finer-grained mass of pinkish felspar, quartz and biotite flakes.

Sections consist, as in [$\frac{1}{740}$], of large partially kaolinised and partially micacised platy crystals of microcline felspar, fewer large quartz plates that are in some cases more or less rounded, and smaller ragged quartz plates, with occasional flakes of brown biotite and grains of iron ore. There are undoubted rounded inclusions of quartz in the microcline, and rounded inclusions of vermicular intergrowth also in the felspar. Irregular lamellation and extinction in the felspar and uneven extinction in the quartz are common. There is some chloritisation of the biotite.

The rock is essentially the same as [$\frac{1}{740}$], *i.e.*, a *microcline-biotite granite.*

[$\frac{1}{738}$]. From Mount Gibbs, Phillips River G.F.

A rather coarse-grained white or light-grey granitic rock with large plates of microcline showing intergrowths of quartz and an approach to graphic structure, and biotite scales in thin streaks, giving in places a suggestion of gneissic structure to the rock. The sections show, as in the previous specimens, large microcline and quartz plates with flakes of biotite and green chlorite. The quartz plates appear in places to be partially granulated, or at any rate broken down into smaller fragments. There is uneven extinction in the quartz and felspar, and irregular lamellation and bending of the lamellae in the felspar, characters due to dynamic strain on the rock. Vermicular intergrowths also occur, some in the microcline.

The rock is again a coarse-grained *microcline-biotite granite.*

It is very evident, then, that these three specimens, though collected from places many miles apart, are all so closely similar both in appearance, structure, and composition that they must be regarded as portions of the same or of a genetically similar mass.

Relation of Group (a) to Group (b):—

In external appearance the two groups are, as already stated, undoubtedly separable. When, however, attention is directed to the composition and structure of the two, a very marked similarity becomes at once apparent. Both groups are microcline-biotite-granite: in both, the main constituents are the same, viz., quartz, microcline, and biotite; and in both, the same peculiarities are manifested, viz., vermicular micropegmatite areas, and inclusions or intergrowths of quartz in the felspar. There are differences between the groups, but these, such as the presence of semi-porphyritic structure, the presence of green chloritic flakes, and the presence of sphene crystals in Group (b), are of minor importance. With regard to sphene, this mineral has not been observed in Group (a), but, on the other hand, it is not observable in all specimens of Group (b). Again, specimens like [$\frac{1}{741}$], which, according to field evidence, are dykes and are connected with the granites of Group (a), are both in external appearance and in composition strikingly similar to [$\frac{1}{738}$].

Since, therefore, the mapping shows the rocks of Group (a) to occur as veins or apophyses, it is probable that the yellow specimens are but apophysal varieties of a main mass of which the rocks of Group (b) are specimens. This being the case, it would appear, further, that the quartz and quartz-felspar pegmatite that form the ore-bodies of the Main Lode are genetically connected with the magma which gave rise to the grey granite. Owing, however, to the impossibility of obtaining further field evidence on this point, no positive assertion to this effect can be made.

7. The Aplite or White Granite Dykes.

These occur as thin veins, varying in thickness from an inch to a few feet. They cut through all the other rocks whose relations with them can be observed. They are comparatively large in number but their chief characters are represented by the following specimens:—

(a) From a depth of 238ft. to 241ft. in the No. 3 Bore:

This is a coarse-grained white granite with felspar, in part microcline, in part orthoclase, in part apparently albite or oligoclase. Small areas of vermicular micropegmatite occur, also small flakes of greenish chloritic biotite and of green chlorite. There are inclusions or intergrowths of quartz in the felspar; and the lamellae of the felspar are in places bent by strain.

(b) From 243ft. to 251ft. in the No. 3 Bore:

This specimen is a fine-grained white granite characterised by small beautiful euhedral red garnet crystals. (Fig. 74.)

(c) From 279ft. to 281ft. in the bore from Weston's Reward:

The rock is a fine-grained white granulitised or granulated, highly felspathic aplite. The plates of felspar and quartz are ragged, granulated at the margins, and broken down in places into small round grains. Bending of the felspar lamellae is again noticeable, and there is rarely a little brown biotite in thin flakes.

(d) The thicker dykes:

One specimen of these shows a fine-grained white facies enclosing a lenticular band of the biotitic granitic gneiss, and while the specimen is fine-grained as a whole. it gradually becomes coarser towards the margin of the xenolithic inclusion. While the enclosing rock is massive, the xenolith is markedly foliated and highly biotitic. In section, the enclosing rock consists of large plates of microcline and smaller plates of quartz. The former are ragged, partially kaolinised, in places broken down into a granular mosaic, in places with many small quartz inclusions, and in places with marked granular and striped intergrowths. The felspars are all more or less kaolinised.

Other specimens are coarse-grained, but with portions so fine-grained as to be felsitic in appearance. These felsitic bands may represent chilled margins.

In general, therefore, the rocks are white in colour, and vary in grain from fairly coarse to a fineness that is almost felsitic. They consist of felspar and quartz, the former being in places largel microcline, but in places orthoclase, and another acid plagioclas Only rarely do a few scales of brown biotite and green chlori appear. In one instance, *i.e.*, at 243 feet to 251 feet in the No. Bore, the granite or aplite contains small red garnets.

Fig. 74.

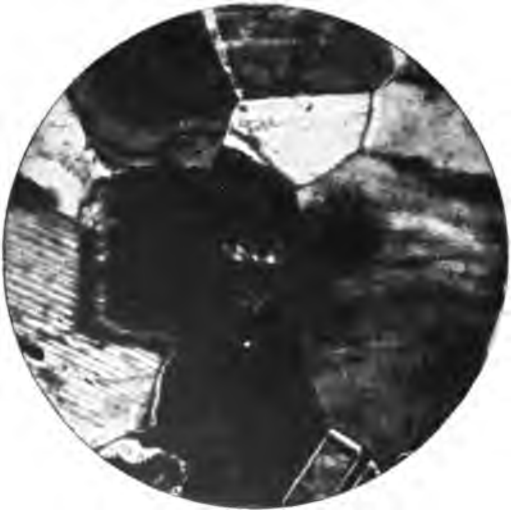

Photo: R. A. Farquharson. Neg. 1618.

$[_{4}{}^{1}{}_{2}]$ 243ft.-251ft. in No. 3 Bore, Edna May: Aplite or white granite with euhedral garnets.

8. THE HILL END AND BATTLER GNEISS.

(a.) *The Hill End Gneiss*:

Two specimens of this $[_{11}{}^{1}{}_{56}]$ and $[_{11}{}^{1}{}_{57}]$ show somewhat different characters.

$[_{11}{}^{1}{}_{56}]$ This is a foliated medium-grained tough grey rock with splashes and strings of brown biotite mica and small pale yellowish-green patches, with some silvery scales of white mica.

In section the rock is a fine-grained granulitic or granular mass of rounded and polygonal mosaic plates of clear felspar and quartz, in which are occasional large platy crystals of felspar generally highly micacised and partially broken down, especially at the margins, into a granular mass of small plates. Through the mosaic, and aggregated at certain spots, are nearly colourless, yellowish wisps of minute hair-like needles so fine as to prevent their optical characters being arrived at. The hairs penetrate both quartz and felspar grains and plates. In certain places they occur as fibrous masses or plates, and, in the fibres, a jointed structure with an indistinct cleavage parallel to their length is noticeable. Moreover, they appear to be biaxial, though the fact that they penetrate other minerals renders their optical characters obscure. Though they resemble tremolitic aggregates, they have been determined in the Survey Laboratory from coarser specimens, in which their character is clear, as sillimanite needles.

A noteworthy feature of the felspars is that most of the large partially micacised and granulated plates have the gridiron structure of microcline, and even some of the smaller grains exhibit the same structure. There are small scales of brown-red biotite scattered over the slide, and occasionally small pale-green chloritic scales with a network of needles resembling sagenite webbing. Kaolinisation is common in the felspar, especially in the large plates. The structure was originally coarse platy, but has been reduced by granulitisation or granulation to a mosaic granular one.

The rock is a foliated granulitic *quartz-felspar sillimanite gneiss.*

[$\frac{1}{1157}$]. This is a dull greyish-white foliated rather fine-grained rock with the foliation marked by strings of biotitic scales, and with splashes and large flakes of silvery mica. In section it is a fine-grained granular mass of quartz and kaolinised and micacised felspar plates, with occasional greenish scales of chlorite, large flakes and platy aggregates of white muscovite, and large platy felspars micacised and kaolinised and partially granulated. Some of the small fibrous chlorite scales have already acquired a brownish biotitic character, and in many the acicular webbing is again visible. Some undoubted grains of tourmaline occur, some calcite, and apparently some zoisite. In some places, large scales of muscovite occur, with a finely fibrous structure resembling that of the doubtful haematite aggregates in [$\frac{1}{1156}$].

The structure is fine granular.

The rock is decidedly of acid character, a granular mass, mostly of quartz and felspar, and interpreted as a *chloritic muscovitic granulitic quartz-felspar gneiss.*

Both [$\frac{1}{1156}$] and [$\frac{1}{1157}$] are obviously varieties of the same rock. In the field the rock is bordered by hornblende schist, and its occurrence distinctly suggests an origin as a dyke, which the occurrence of tourmaline in [$\frac{1}{1157}$] strengthens.

(b) *The Battler Gneiss*:

This is typically represented by [$\frac{1}{1158}$].

The rock is a fine-grained yellowish-grey finely foliated rock with splashes and strings of a brownish biotitic mineral. The latter, often intimately mixed with the rock mass, give it a brownish tint. On the cross fracture the rock is pale-grey in colour and almost felsitic in texture.

In section, it consists of a fine granular or granulitic mass of clear quartz, and micacised as well as kaolinised felspar plates, with scattered scales and imperfect bands of yellowish-green chlorite, and of a brown-yellow biotitic mineral that is probably chlorite in course of alteration to biotite. Many of the felspar grains exhibit the grid-iron structure of microcline, while others show the broad albite twinning, and some no twinning at all.

The rock is a fine-grained almost felsitic *granular quartz-felspar gneiss.*

There is no doubt that both this Battler gneiss and the gneis from Hill End are varieties of the same rock.

As to the affinities of the gneiss with the other rocks in the field not much can be said. The only other rock with which a connectio could be established is the Edna May grey-biotitic gneiss. Th Battler and Hill End gneiss, however, appear distinctly more acid hornblende was not found in it in any section; and from its occurrence it is distinctly intrusive into the hornblende schists. On th other hand, particularly in the Hill End gneiss, brown-red biotit scales and patches occur identical with those in the Edna May gneiss and chlorite flakes in course of alteration to the biotite are by n means uncommon. The structure, however, and the composition of the two gneisses are to a considerable extent dissimilar, for in the Battler and Hill End type microclinic plates are common, there is intense micacisation of the felspar and an occasional occurrence of tourmaline, while these characters are absent from the Edna May type.

In spite, therefore, of certain similarities, and on account of differences in structure and composition, and the absence of any field connection, it is not feasible to correlate these rocks with the Edna May gneiss. It is possible, of course, that they may represent more acid apophyses of the intrusion which may have given rise to the Edna May rock, but in this case there must have been a considerable variation in structure and composition, though the chlorite of the Battler gneiss may represent former hornblende. The evidence at present available is too sparse and obscure to enable any definite conclusions to be drawn.

B.—THE DOLERITE DYKES FROM THE CORINTHIAN MINE.

These are dense-black, fresh, medium to fine-grained rocks, varying in width from two feet to twenty-six feet. They occur distinctly intruding the granite. Their chief characters are illustrated by [13945] and [13944]. The former, in section, consists of large columnar felspars and large grains of augite as well as numerous smaller laths of felspar and smaller grains of augite, with a subophitic relation between the crystals of the two minerals. Grains of iron ore are common. The latter [13944] consists, in section, of altered large porphyritic felspars and occasional large grains of augite in a fine-grained ground-mass consisting of very thin laths of felspar and grains of partially chloritised augite, with patches of iron ore. This specimen is a porphyritic basaltic dolerite with strong resemblances to an augite-andesite.

The mineral composition of both rocks is the same, but [13944] has decidedly more of a basaltic structure. Both the microscopic and the field evidence point to its being a chilled marginal facies of the normal dyke represented by [13945].

C.—ROCKS FROM THE BULLFINCH AREA.

These comprise specimens collected some years ago by Mr. C. B. G. Gibson and those collected by Mr. Blatchford during the recent survey.

Mr. Gibson's rocks are represented by [11523], [11519], [11518], [11517].

[11523.] This is a confusedly fibrous epidiorite consisting of fibrous wisps, plates with a fibrous fringe, and sheaves of nearly colourless hornblende separated by a fine-grained microcrystalline mosaic of felspar. The latter represents original platy felspars which dynamic stress has reduced to mosaic. In places, remains of the original columnar crystals may still be seen, and since these still form a kind of coarse plexus it is probable that the rock was originally a coarse dolerite or gabbro, such as those described in Bulletin 49, from the Southern Cross area.

[11520] is very similar, but the hornblende is greatly predominant over the felspar, and the grain is fine.

[11519.] This is a coarse-grained rock composed of large ragged extremely fibrous plates of pale-green nearly colourless uralitic hornblende, with a few plates of yellowish chlorite. There is a noticeable fibrous margin to the plates, though many of them are intensely fibrous throughout. Very little felspar is visible, though it may to some extent be obscured by the hornblende fibres.

The rock is a fibrous uralitic hornblendite, probably derived originally from a coarse gabbro or pyroxenite.

[11518.] This rock is a very fibrous uralitic epidiorite in which felspar is rather poorly developed, though probably obscured by the hornblende fibres. A little zoisite appears to be present. The rock is essentially similar to [11523.]

[11517.] A fine-grained schistose fibrous quartz epidiorite with the ferro-magnesian and the colourless constituents in about equal amount. The felspar is in small plates largely in process of granulitisation and kaolinisation, and, like the hornblende, elongated somewhat in the direction of schistosity. Quartz grains are but sparsely distributed.

It will be seen, therefore, that the rocks are all either fibrous epidiorites or hornblendites, and all have originally been derived from gabbro or pyroxenites. Mr. Gibson in his report on the Bullfinch property divides the greenstones into two series, the Older Greenstones and the Newer Greenstones. The former he considers to have been originally probably fine-grained diabases ultimately altered by dynamic metamorphism into schistose epidiorites. The latter, he states, are essentially coarse-grained, generally sheared or schistose, and were originally coarse-grained pyroxenites.

Now, while coarse-grained amphibolites and fine-grained epidiorites undoubtedly occur, particularly around Southern Cross, it must be carefully noted that often in the finer-grained epidiorites, coarser amphibolite and even hornblendite bands or lenticles may and do occur, and these are frequently but hornblendic segregations in the epidiorite rock. Further, though some of the greenstones may appear to have been derived from diabases or dolerites and others from pyroxenites, it by no means follows that the different facies are of different age. In doleritic and gabbroid masses it is quite common to find gradual variations from a rock rich in felspar and augite—a gabbro—to one from which the felspar is absent or nearly so, which consists almost wholly of pyroxene—a pyroxenite. Though the end products of the variations appear mineralogically and structurally different, the occurrence of transition stages proves the genetic connection between them. The hornblendic derivatives of these end products would be, in the one case, felspathic amphibolites or epidiorites, in the other, hornblendites, yet both would be of the same age and origin.

The specimens collected by Mr. Blatchford are from the rock in the drive from the main shaft in the Bullfinch Mine at the 410ft. level. The numbers of the series occur, roughly, in the following order, starting from the shaft *:—

[$\frac{1}{1167}$], [$\frac{1}{1166}$,] [$\frac{1}{1168}$], [$\frac{1}{1169}$], [$\frac{1}{1170}$], [$\frac{1}{1171}$], [$\frac{1}{1164}$], [$\frac{1}{1165}$], Dolomite lode, [$\frac{1}{1172}$],]$\frac{1}{1173}$].

The characters of the rocks are as follows:—

[$\frac{1}{1164}$.] A fine-grained dark grey-green hornblendic rock with grains of coarser and greener hornblende fibres and small patches of a brownish tint. In section, the rock is a medium to fine-grained epidiorite with a little quartz in addition to felspar. It consists of a ragged platy fibrous mass of greenish hornblende, the plates sometimes forming a loose network or patchwork with the interspaces occupied by a few grains of a quartz-felspar mosaic. In places, the quartz-felspar mass is preponderant, the hornblende occurring only in isolated plates or strings, but generally hornblende forms most of the rock. The brownish-green patches are due to the presence of some flakes of brown-red chloritic biotite. A slight tendency to parallel arrangement is noticeable in many of the hornblende plates. Accessories are few, and the structure is platy granular.

[$\frac{1}{1165}$.] The rock is very similar in external appearance to [$\frac{1}{1164}$]. Sections of it also resemble those of [$\frac{1}{1164}$], but the hornblende is in fibrous stringy plates, with the strings forming an indistinct foliation. The mineral composition is the same as in [$\frac{1}{1164}$] but quartz is less common. Slight chloritisation is noticeable in the hornblende. The rock is essentially the same as [$\frac{1}{1164}$], but with a tendency to schistosity.

An analysis of the rock [G.S.L. 9726D] in the Survey Laboratory gave these results:—

SiO_2	52·20
Al_2O_3	14·22
Fe_2O_3	·87
FeO	7·75
MnO	·31
MgO	8·71
CaO	12·85
Na_2O	·56
K_2O	·14
H_2O hyg.	·07
H_2O comb.	1·72
TiO_2	·69
CO_2	·29
P_2O_5	·09
FeS_2	·24
Cr_2O_3	...
V_2O_3	...
Total	100·71

Analyst—H. Bowley.

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* Plate XI.

[$\frac{1}{1173}$] is a somewhat sheared, fine-grained, faintly banded dark-brown and green rock, very similar to the brownish portions of [$\frac{1}{1184}$]. In section it consists of a very fine-grained ground made up of numerous small plates and strings of a yellow-brown pleochroic biotitic chlorite, with here and there areas in which ragged prisms of greenish hornblende appear, sometimes chloritised. All through the brownish scales are very small grains of felspar. Rarely small green chlorite scales occur mixed with the brown, and a little calcite appears in places. Quartz was not definitely recognised, though a little may be present. Accessories are few. There is little doubt that the brown flakes have been derived from the green, and that the rock is a facies or variation of [$\frac{1}{1184}$] and [$\frac{1}{1183}$] more affected by dynamic stresses.

[$\frac{1}{1185}$] and [$\frac{1}{1187}$]. These are both fine schistose dark-grayish green chloritic rocks with faint sheen. On the cross fracture they appear darker green and granular. Sections consist of stringy patches and imperfect bands of green fibrous chlorite, in places charged with black grains of iron ore, with the patches and bands separated by a mosaic of quartz plates of various sizes from small grains to large plates. These quartz areas often also contain chlorite scales. Small fibrous nests of colourless hornblende needles appear occasionally in the chlorite patches.

The rocks are both chlorite-quartz schists. They have undoubtedly the structure of many schistose epidiorites, but differ from these in having chlorite instead of hornblende, and quartz instead of felspar. They are exactly what would result from the alteration of the hornblende of the epidiorites to chlorite, and the granular felspar mass to quartz.

An analysis of the rock [G.S.L. 9725D] in the Survey Laboratory resulted as follows:—

SiO_2	48·35
Al_2O_3	13·11
Fe_2O_3	2·77
FeO	15·02
MnO	·07
MgO	11·86
CaO	·28
Na_2O	·30
K_2O	·04
H_2O hyg.	·04
H_2O Comb.	7·30
TiO_2	1·20
CO_2	·15
P_2O_5	·11
FeS_2	·09
Cr_2O_3	...
V^2O_3	...
Total	100·69

Analyst—H. Bowley.

The analysis confirms the microscopic determination of the rock as a hydrous alumina-magnesia-iron silicate with quartz.

[$\frac{1}{1169}$], [$\frac{1}{1170}$, $\frac{1}{1171}$]. All these rocks are very dark-grey, soft, talcose rocks with veinlets of pure greenish-white talc. They are all more or less sheared.

In section they consist almost entirely of a dense mass of pearly talc scales in which are irregular grains, granular aggregates, and patches of a carbonate, and in some cases, patches of pale greenish, nearly isotropic chlorite. In the talc areas are grains of black iron ore and a little pyrites.

The rocks are sheared, dark-grey, *talc-carbonate rocks,* probably derived by chemical and dynamical alteration from amphibolites.

[$\frac{1}{1172}$] A much weathered, soft, greenish-yellow highly schistose rock. Sections consist of numerous fine strings and aggregates of strings forming bands, of yellowish-green chloritic scales, with occasional small lenticular patches and strings of colourless iridescent scales that are either talc or sericite, probably the former. In the green chloritic strings are a few small grains of a colourless mineral that is either quartz or felspar.

The rock is a weathered finely foliated *chloritic schist.*

[$\frac{1}{1163}$] A very fine-grained, finely, though indistinctly foliated, brownish-black or grey rock with a faint sheen and with a suggestion of corrugation on the surfaces. The rock has almost a flinty appearance.

In section, the rock is composed of an extremely fine-grained mass of rounded and polygonal felspar plates and small patches of slightly coarser texture, in which are streaks of greenish chloritic scales, and strings and scaly patches of small flakes of colourless mica. The chloritic streaks are not infrequent, and in places appear almost as thin bands, while the coarser felspar plates, most of which are slightly kaolinised, occur largely in association with these bands. Rutile needles are observable in the chlorite scales. A noteworthy feature of the rock is the occurrence in association with the chloritic streaks of minute highly pleochroic greenish needles. These have marked jointing, apparently straight extinction, and strong absorption in a direction at right angles to that in biotite—in other words, they have characters agreeing with those of tourmaline. In some cases, however, a faint cleavage is noticeable, and, so far as could be made out, the mineral is biaxial. The green tones of the mineral, moreover, are rather those of actinolite than tourmaline. The needles, therefore, are with doubt referred to actinolite.

There is a marked parallelism in the alignment of the chloritic streaks, the green needles and the mica scales and needles. The structure of the rock is very fine granular, and appears to be due to the granulation of a highly felspathic facies, probably originally with hornblende. of the slide is that observable in the more felspathic portions [$\frac{1}{1164}$],

The origin of the rock is not clear. To some extent, the appearance and in default of clearer evidence the rock is put down as a very fine-grained foliated highly felspathic facies of a greenstone that has been completely granulated.

The interpretation of the section, owing to the very small amount of evidence procurable, is very difficult. [$\frac{1}{1166}$] and [$\frac{1}{1167}$], as has been shown are chloritic-quartz schists which, in structure at any rate, strongly suggest that they have been derived from a foliated or schistose epidiorite. They are devoid of lime. [$\frac{1}{1169}$], [$\frac{1}{1170}$], and [$\frac{1}{1171}$], again, are chloritic talc-carbonate rocks, sheared and with a fairly large development of carbonates. It would seem, therefore, that these three were amphibolites which occurred in a zone of intense shearing and chemical action that resulted in the alteration of the amphibolite to talc, chlorite, and a carbonate. $_{1}{}^{1}{}_{64}$] and [$_{11}{}^{1}{}_{67}$], on the margin of this zone, were not altered to the same extent, but through chemical action their lime content was removed, and it may have contributed to the carbonate development in [$_{11}{}^{1}{}_{69}$], [$_{11}{}^{1}{}_{70}$], and [$_{11}{}^{1}{}_{71}$]. It is possible, of course, that $_{11}{}^{1}{}_{64}$] and [$_{11}{}^{1}{}_{67}$] may have been hornblende schists from which felspar has always been absent, but this is less likely than the former explanation.

The occurrence of [$_{11}{}^{1}{}_{64}$] and [$_{11}{}^{1}{}_{65}$], both fine-grained fresh epidiorites, with, on the one side, the talc-carbonate rocks [$_{11}{}^{1}{}_{69}$] $_{11}{}^{1}{}_{70}$], and [$_{11}{}^{1}{}_{71}$], and on the other, a band or lode of dolomites, is difficult to account for. The most feasible explanations seem to be that either [$_{11}{}^{1}{}_{64}$] and [$_{11}{}^{1}{}_{65}$] represent a later epidiorite intrusion into the altered rocks, or they are massive portions of the rock that have escaped the shearing and chemical alteration that have affected the surrounding country.

D.—THE GREENSTONES FROM GOLDEN VALLEY.

Typical specimens of these are:—

[$_{7}\frac{1}{50}$] from G.M.L. 1899.
[$_{7}\frac{1}{51}$] from Mount Colreavy.
[$_{7}\frac{1}{52}$] from G.M.L. 1263.
[$_{7}\frac{1}{49}$] from G.M.L. 1263.

The chief characters of the rocks are as follows:—

[$_{7}\frac{1}{50}$] G.M.L. 1899:

This is a very coarse-grained platy, dark grey-green hornblende rock resembling in appearance the lustre-mottled amphibolites. In section, it consists wholly of large ragged plates of an intensely and finely fibrous uralitic hornblende, with here and there in the plates a remnant of less fibrous hornblende, to which the former acts as a fringe. A little reddish-brown biotitic chlorite is present. No felspar was observed. There are a few grains of iron ore.

The rock is a very coarse *uralitic hornblendite,* probably originally derived from a pyroxenite.

[$_{7}\frac{1}{51}$] Mount Colreavy:

A fine-grained somewhat sheared dark grey-green rock with chloritic sheen on the surface. It consists of numerous feathery, sheafy, and divergent acicular groups of a pale green very fibrous hornblende, with the interspaces occupied by a minute felspathic mosaic due to the breaking down of felspar plates. (Fig. 75.)

The rock is a fine-grained *fibrous epidorite* similar to those described from Bullfinch, *e.g.* [11523].

[$_{7}\frac{1}{52}$] G.M.L. 1263:

A fine-grained dark-green hornblendic rock. It is a felted fibrous and platy hornblendite composed of a dense confused mass or felt of small ragged fibrous plates, needles, prisms, and rods of a pale green hornblende, with numerous small aggregates of grains of iron ore, and occasional small grains of clear colourless felspar. A little kaolinised felspar also appears in places.

[$\frac{1}{740}$.] Very similar in hand specimens to [$\frac{1}{753}$], and almost iden
cal with it in section, though a little finer in grain and with a den
felt.

The rocks, therefore, from this locality are either hornblendi
of coarse grain or fibrous epidiorites of finer grain.

Fig. 75.

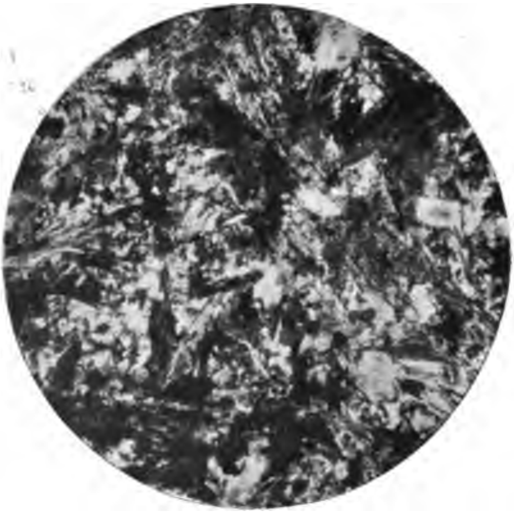

Photo: R. A. Farquharson. Neg. 1619.

[$\frac{1}{751}$] **The fine-grained fibrous epidiorite, similar to the epidiorites described from Bullfinch.**

E.—THE GREENSTONES OF HATTER'S HILL.

These are represented by the four rocks [$\frac{1}{755}$], [$\frac{1}{743}$], [$\frac{1}{739}$] and [$\frac{1}{740}$].

$\frac{1}{755}$] is a fine-grained dark grey-green finely foliated hornblendic rock, consisting of numerous rods of green hornblende arranged parallel and separated by small clear grains of felspar. Some apatite and doubtful zoisite are observable.

The rock is a fine-grained acicular *hornblende schist.*

[$\frac{1}{743}$] is a coarse-grained massive dark-green platy hornblende rock. In section it is composed of large ragged plates of green hornblende, more or less fibrous and contorted, and indistinct lamellated plates of a plagioclase obscured by needles and radiated tufts of hornblende and by an evident granulitisation. Many of the hornblende plates are partially mashed and are perforated by grains of the felspar.

The rock is a massive, very coarse-grained *crushed amphibolite* or *epidiorite,* derived originally from a gabbro with excess of pyroxene.

$[\frac{1}{739}]$ is a medium-grained dark grey-green hornblendic rock without foliation, but with white granular felspar associated with the hornblende. In section, it proves to be a *crushed quartz-epidiorite*, doubtless a finer-grained facies of $[\frac{1}{743}]$.

$[\frac{1}{740}]$ is identical with $[\frac{1}{743}]$.

There is no doubt that $[\frac{1}{739}]$, $[\frac{1}{740}]$, and $[\frac{1}{743}]$ are all varieties of the same rock mass.

As for $[\frac{1}{735}]$ it differs from these in (a) the presence in it of a marked foliation, (b) the absence of the ragged platy forms, and the exclusive occurrence in it of prismatic rods, (c) complete granulitisation of its colourless constituents. Since, however, variations from amphibolite and epidiorite to hornblende schist are well-known in greenstone areas of this nature, it is probable that $[\frac{1}{735}]$ is merely a more intensely metamorphosed variety of the rock mass represented by the other three specimens.

F.—SOME GRAPHITISED ROCKS OF DOUBTFUL ORIGIN.

$[\frac{1}{8}]$: From Comstock Lease No. 2111, Boodalin:

This is a very fine-grained, dirty greyish-black, somewhat porous, graphitic rock with numerous minute white scales or rods all arranged with the long axes parallel. There is a suggestion of shearing in the specimen, and the specific gravity is light. Owing to the denseness of grain, the rather soft nature of the specimen and the graphitic content, it is very difficult to obtain a section of the rock of any value. It is possible, however, to make out that the body of the rock is composed of small quartz grains heavily charged with a black dust, of which some particles have the appearance in reflected light of graphite scales. Doubtless there is a considerable amount of amorphous graphite as well. In addition to these constituents, there are occasional pale yellow fibrous flakes resembling decomposed mica, and, rarely, rather large areas of minute scales of mica heavily charged with the black dust. These large micaceous aggregates are of obscure origin, but are consistent with a derivation from original chiastolite.

From the character of the rock and from comparison with undoubted chiastolite shales from the same field, it is probably a sheared, much altered, *graphitic shale of the chiastolite-shale series.*

$[\frac{1}{4}]$: From Comstock Lease No. 2111, Boodalin:

An extremely decomposed rock, apparently sheared or indistinctly laminated, somewhat porous, extremely ferruginous, and of a brick-red colour, with numerous pale slate-blue rounded forms that are soft and granular and in places blackish. The rock is too much altered for sectioning, but appears to be slightly graphitic. The bluish forms were at first thought to be flinty, but their soft nature indicates that they are probably decomposition products. Tests, however, with the blow-pipe failed to reveal a thoroughly aluminous character, but this may have been due to the presence of iron or carbon, and it is probable that they are decomposition products of andalusite.

The rock is of doubtful origin, but is classed as a *weathered ferruginous clayey product of an andalusite shale.*

[$\frac{1}{852}$] East of G.M.L. 2249 and 2251, Golden Valley:

A finely sheared, almost schistose greyish-black graphitic qua rock, with angular quartz forms on the shear surfaces.

Slides show the rock to consist almost entirely of ragged round and angular quartz plates surrounded by quartz mosaic of vario degrees of fineness, with wavy strings, streaks and patches of black du apparently graphitic, scattered in general parallel alignment throu the mosaic, probably along the shear planes. Many of the plates quartz are partially granulated at the margins, and there is eviden that lenticular patches of mosaic represent disintegrated or broken do plates of quartz.

The rock is of indefinite structure but appears to be a high sheared *graphitic quartz breccia,* possibly with some cement secondary silica.

[$\frac{1}{853}$] G.M.L. 2239, Golden Valley:

A fine-grained, finely laminated, dark greyish-black, high siliceous rock, in places with granular haematite on the surfaces the laminae. A curving of the laminae, and in places a *contortio* indicate pronounced shearing since formation.

The rock is of doubtful origin. Its laminated character sug gests a finely *laminated shale* that has been completely silicified.

[$\frac{1}{854}$] G.M.L. 2239, Golden Valley:

(2.) A coarse-grained greyish-white siliceous rock with a pinkis tinge, apparently composed of angular and more or less rounded frag ments of quartz, cemented by quartz, and with a sheared structure visibl on one fracture surface.

The rock is again of doubtful origin, but appears to be *quartz breccia,* with quartz fragments cemented by silica. Som rounded quartz forms have a conglomeratic appearance.

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I.—MAPS.

Geological Map of Northampton: by A. Gibb Maitland. Scale, 20 chains per inch. Two sheets. Price, 2s. 6d. 1898.

Geological Map of the North Lead, Kanowna: by Torrington Blatchford. Scale, 8 chains per inch. Price, 1s. 1901.

Geological Map of Kalgoorlie: by A. Gibb Maitland and W. D. Campbell. Scale, 10 chains per inch. Six sheets. Price, 21s. 1902.

In preparation:

Geological Sketch Map of Western Australia: by A. Gibb Maitland. Scale, 1/1,584,000. Four sheets.

II.—REPORTS.

Reports by the Government Geologist in connection with the Water Supply of the Goldfields, containing—(*a*) Coolgardie and Kalgoorlie; (*b*.) Menzies. (*c*.) Cue. Price, 1s. 1897.

Annual Progress Report for the Year 1897. (*Out of print.*) 1898.

Annual Progress Report for the Year 1898, containing—
Location 1830, Avon District; Gold Discoveries on the Ditchingham Estate, Brunswick River; Collie Coalfield; Proposed Boring for Artesian Water in the Eastern Agricultural Districts; The Country between Cape Riche and Albany; The Wongan Hills; The Artesian Water Prospects of the vicinity of Moora; A Geological Reconnaissance of the Country at the heads of the Murchison and Sandford Rivers, in the Murchison, East Murchison, and Peak Hill Goldfields; Gold Discoveries at Donnybrook; Norseman Public Battery, and the use of Brines in Gold Extraction; Mineral Waters; Mineralogical and Petrological Notes; Kalgoorlie; Menzies. Price, 1s. 1899.

Annual Progress Report for the Year 1899, containing—
Notes on the Greenbushes Tinfield; Boring for Water at Mulgarrie; Boring for Water at Hayes' New Find; the Geology of the Bardoc District; On the Development of Mining in the locality of Donnybrook; The Geology of the North Lead, Kanowna; The Kanowna Great Boulder, G.M.L. 885x; Mineral Waters; Composition of Native Gold; Greenbushes Tin Ore; Cobalt Ores; Menzies Goldfield; Kalgoorlie Goldfield; Coolgardie Goldfield. Price, 1s. 1900.

Annual Progress Report for the Year 1900, containing—
Kalgoorlie Goldfield; Phillips River Goldfield; Gold Finds on the Preston and Ferguson Rivers; The Present Condition and Future Prospects of the Greenbushes Tinfield; Boring for Coal near Albany; North Lead, Kanowna; Bulong Deep Leads; Coolgardie Deep Leads; Alluvial Deposits, Donnybrook Goldfield; Subsidy to the Norseman Gold Mines, Ltd.; Gascoyne District; Extension of Artesian Water-carrying strata from South Australia. Price, 1s. 1901.

Annual Progress Report for the Year 1901, containing—
Kimberley; Uaroo Find, Ashburton River; Gascoyne; The Island, Lake Austin; Mount Ida; Yardarino Bore; The Dundas Goldfield; The Phillips River Goldfield; Norseman Gold Mines, Ltd.; Alluvial Deposits, Siberia. Price, 1s. 1902.

Annual Progress Report for the Year 1902. (*Out of print.*) 1903.

Annual Progress Report for the Year 1903. (*Out of print.*) 1904.

Annual Progress Report for the Year 1904, containing—
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Annual Reports—*continued.*

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Annual Progress Report for the Year 1906, containing—
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Artesian Water Boring in the Murchison, Gascoyne, and Kimberley Districts; The Country between the Gascoyne and Roebourne; Boring for Coal at Depôt Hill, Irwin Coalfield; Boring for Coal at Eradu, Greenough River; Deep Boring on Fraser's Mine, Southern Cross; Alternative Dam Site at Kelmscott; The Mount Malcolm Copper Mine, Eulaminna; Guano Deposits at Watheroo; Reported Gold Discoveries at Mundijong; Boring for Artesian Water, West Kimberley; Boring near Wyndham; Wolfram and Tin near Brookton; Copper Deposits at Yandanooka. Price, 1s. **1908.**

Annual Progress Report for the Year 1908. (*Out of print.*) **1909.**

Annual Progress Report for the Year 1909. (*Out of print.*) **1910.**

Annual Progress Report for the Year 1910, containing—
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Annual Progress Report for the Year 1911 (Administrative Report only) Price, 1s. **1912.**

Annual Progress Report for the Year 1912. (*Out of print.*) **1913.**

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LXXII. Palæontological Contributions to the Geology of Western Australia, VI.: by F. Chapman 1917.

In the Press.—The Western Australian Handbook, edited by A. Gibb Maitland, Government Geologist.

In preparation:—

The Geology and Mineral Resources of the Country South of Nullagine: by H. W. B. Talbot, Field Geologist.

The Mining Geology of Niagara, Kookynie, and Tampa, North Coolgardie: by J. T. Jutson, Field Geologist.

The Artesian Water Resources of Western Australia: by A. Gibb Maitland, Government Geologist.

IV.—MEMOIRS.

In preparation:—

I. The Geology and Mineral Resources of Western Australia: by A. Gibb Maitland.

Detailed Lists to be had on application at the Geological Survey Office, Perth, Western Australia.

1917.

WESTERN AUSTRALIA.

GEOLOGICAL SURVEY.

BULLETIN No. 72.

Palæontological Contributions
TO
The Geology of Western Australia.

SERIES VI., Nos. XI. and XII.

BY

F. CHAPMAN, A.L.S., F.R.M.S., Etc.,
Palæontologist, The National Museum, Melbourne, Victoria,
and
R. ETHERIDGE, Jr.,
Curator, The Australian Museum, Sydney, New South Wales.

Issued under the Authority of
THE HON. R. T. ROBINSON, K.C., M.L.A., MINISTER FOR MINES.

WITH FIFTEEN PLATES AND ONE MAP.

PERTH:
BY AUTHORITY: FRED. WM. SIMPSON, CONTROLLER OF PRINTING.
1917.

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PREFATORY NOTE.

The two contributions to which the Geological Survey is indebted to the authors have been received since the publication of the last of the palæontological series (Bulletin 58) was issued in 1914.

The first contribution is from the pen of Mr. Frederick Chapman of the National Museum, Melbourne, who has been engaged for a year or two past upon a study of the *Foraminifera* and *Ostracoda* of the Gingin "Chalk," and in this report makes an important contribution to the palæontology of the Cretaceous Rocks of the State, as developed in this locality. Mr. Chapman, who is recognised as one of the world's leading specialists on Foraminifera, regards the Gingin beds as belonging rather to the Albian-cum-Cenomanian horizon or the lower part of the Upper Cretaceous, than the Aptian or Lower Cretaceous; a correlation which is paralleled as the result of his investigations into the Ostracods from Gingin.

It is interesting to note that in Bulletin 55, which contains an account by Mr. Etheridge of some Cretaceous fossils from Gingin, the close relationship between the beds of India and Western Australia was pointed out. The Cretaceous Rocks of South Africa, as pointed out by Mr. Chapman, show a striking faunal resemblance to those of Australia, and thus afford another instance of the intimate geological kinship existing between the countries bordering the Indian Ocean—a resemblance, as has already been pointed out, obtaining in the Pre-Cambrian, and the Palæozoic Rocks of these widely separated areas.

The second contribution by Mr. R. Etheridge upon the occurrence of *Girvanella* in the Cambrian Rocks of Kimberley makes a further addition to our scanty knowledge of the palæontology of this important formation.

A. Gibb Maitland

GOVERNMENT GEOLOGIST.

Geological Survey Office,
Beaufort Street, Perth,
16th January, 1917.

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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA.

LIST OF OFFICERS.

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Do.	H. W. B. Talbot
Do.	E. de C. Clarke
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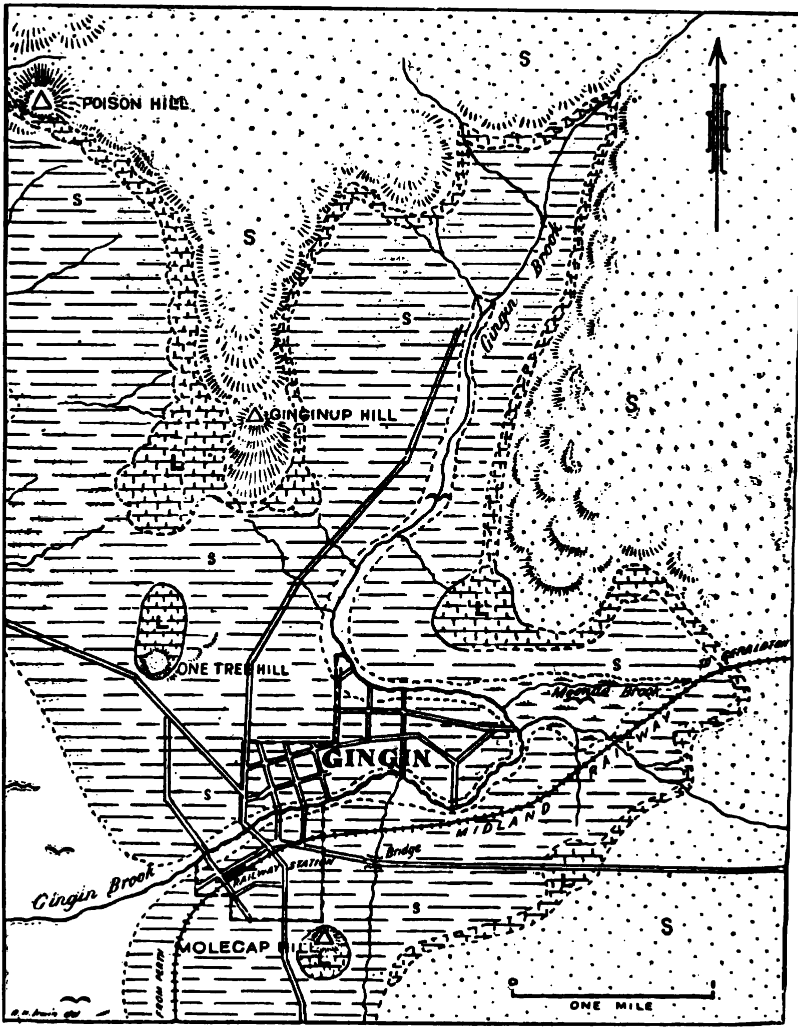
*Absent with Expeditionary Forces.

GEOLOGICAL MAP OF GINGIN.

Geol. Survey. Frontispiece. *Bulletin No. 72.*



EXPLANATION

ALLUVIUM	~
FERRUGINOUS SANDSTONE	S
GINGIN "CHALK" & CLAY	L
VARIEGATED CLAY (? Shale)	s

Boundaries obscured by drift sand and superficial deposits.

Palæontological Contributions

TO

The Geology of Western Australia.

SERIES VI.

XI.—Monograph of The Foraminifera

AND

Ostracoda of The Gingin Chalk.

BY

FREDERICK CHAPMAN, A.L.S., F.R.M.S., Etc.,

Palæontologist, The National Museum, Melbourne.

WITH FOURTEEN PLATES, I.—XIV.

Introduction.

The highly fossiliferous rock from One Tree Hill, Gingin, Western Australia, is remarkable for being the only known occurrence of an Australian Chalk so nearly equivalent in age, structure, and organic contents to the Chalk of Upper Cretaceous age in Europe and North America.

Our knowledge of this Chalk, up to the present, has been well summarised by Ludwig Glauert,* formerly Field Geologist to the Western Australian Geological Survey, who gives a plan and section of the geology of the district. The section at One Tree Hill Quarry recorded by Glauert is:—

Soil and subsoil, averaging 12 inches.
Band of white limestone without fossils, 18 inches.
Bed of Chalk, richer in Alumina and Silica as it is followed downwards; at 15 feet resembling a greenish glauconitic clay.

The chemical composition of this Chalk is given by the Government Geologist of Western Australia, Mr. A. Gibb Maitland, in a note to Mr. Howchin's paper on the "Foraminifera from a Calcareous Marlstone, Gingin,"* the analysis of which was made by E. S. Simpson:—

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* The Geological Age and Organic Remains of the Gingin "Chalk."—Bull. Geol. Surv., W. Australia, No. 36, 1910, pp. 115-127.

Silica	15·09
Carbonic Acid	33·02
Sulphuric anhydride	·13
Lime	42·41
Magnesia	1·32
Iron protoxide	1·16
Iron peroxide	trace
Alumina	3·15
Water (combined)	1·18
Water (hygroscopic)	1·99
	99·45

The large fossils obtained from the Gingin Chalk have been already described by R. Etheridge, jun., whose paper "The Cretaceous Fossils of the Gingin Chalk"† enumerates a Sponge, a Coral, Echinoid spines, Worm tubes, a Cirripede, Brachiopods, Bivalves, Gasteropods, Cephalopods and Fish teeth. In comparing the Gingin Chalk with the Cretaceous elsewhere, Mr. Etheridge‡ believes it to be connected with the Indian Cretaceous System, which has "been paralleled with the European Upper Cretaceous." At the same time Mr. Etheridge points out that the relationship of the Western Australian fossils is rather with the Rolling Downs Formation than with the Desert Sandstone, generally termed "Upper Cretaceous."

In Mr. Walter Howchin's paper already referred to,§ a list of the Foraminifera from Gingin, together with comments on their age and distribution, is given; in all 37 species. These are now included together with the results of an examination of a large quantity of material which the Government Geologist of Western Australia has placed in my hands for description. Before undertaking the investigation of this material Mr. Howchin had signified his wish that I should amplify the work on this particular rock, upon which he had already written. It is only right to state here that the sample with which Mr. Howchin was supplied was not nearly so rich as that forming the basis of the present work.

NOTES ON THE WASHINGS OF GINGIN CHALK.

The finest material derived from the washings consists largely of the somewhat problematic algæ termed coccoliths. These bodies, shaped something like flattened shirt-studs, are, in the fossil condition, very characteristic of the Upper Cretaceous in

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* Bull. Geol. Surv., W. Australia, No, 27, 1907, p. 38.
† *Ibid.*, No. 55, 1913, p. 9.
‡ Loc. cit., p. 24.
§ Bull. Geol. Surv., W. Australia, No. 27, 1907. p. 38.

Europe, but are not confined to this horizon. They are also met with sparingly in the Lias, as recorded by Rothpletz and Schwarz, and more abundantly in the Tertiary marls of Barbados : while, in the living condition they form a large proportion of the finer part of *Globigerina* ooze. The medium fine washings are crowded with the tests of *Guembelina globulosa,* together with some *Globigerinae* as *G. aequilateralis* and *G. marginata,* and *Anomalina ammonoides.* Other organic particles consist of sponge spicules and prismatic fragments of *Inoceramus* shells.

The coarser washings are mainly foraminiferal tests and valves of Ostracoda with some shell-fragments and an occasional ossicle of *Antedon.* The abundance of the microzoa resembles that seen in washings of the Chalk-marl of Kent.

PREVIOUS RECORDS OF CRETACEOUS FORAMINIFERA IN OTHER PARTS OF AUSTRALIA.

Mr. Walter Howchin, F.G.S., has published a complete census of the Cretaceous Foraminifera of Australia to 1893, in the Report of the Adelaide Meeting of the Australasian Association for the Advancement of Science (September, 1893). Fifty-six species are listed therein. Of these, twenty are common to the locality of Gingin, viz. :—

Sigmoïlina celata, Costa sp.
Haplophragmium agglutinans, d'Orb. sp.
Placopsilina cenomana, d'Orb.
Ammodiscus incertus, D'Orb. sp.
Verneuilina [*Guembelina*] *polystropha,* Reuss. sp.
Gaudryina pupoides, d'Orb.
Nodosaria communis, d'Orb.
Nodosaria soluta, Reuss.
Vaginulina legumen, L. sp.
Marginulina costata, Batsch sp.
Marginulina glabra, d'Orb.
Cristellaria acutauricularis, F. and M. sp.
Cristellaria gibba, d'Orb.
Cristellaria schloenbachi, Reuss.
Cristellaria rotulata, Lam. sp.
Polymorphina angusta, Egger.
Polymorphina lactea, W. and J. sp.
Anomalina ammonoides, Rss. sp.
Truncatulina lobatula, W. and J. sp.
Pulvinulina elegans, d'Orb. sp.

By far the larger number of the Cretaceous species previously known were obtained from Central Australia by Mr. Howchin, who described the fossils obtained by boring for artesian water at Hergott, Tarkaninna, Mirrabuckinna, William Creek, and Wilcannia. From these artesian bores fifty-one species were recorded.

Two new species were described by Mr. Howchin,* viz., *Haplophragmium australe* and *Patellina jonesi*, but these have not yet been met with at Gingin.

The Tarkaninna bore passed through 1,226 feet of Cretaceous rocks. Twenty species of foraminifera were found in this material by Mr. Howchin. They are:—

Hyperammina vagans, Brady.
Reophax fusiformis, Will. sp.
Haplophragmium agglutinans, d'Orb. sp.
Haplophragmium canariense, d'Orb. sp.
Haplophragmium australe, Howchin.
Thurammina compressa, Brady
Sigmoïlina celata, Costa sp.
Bigenerina digitata, d'Orb.
Bigenerina nodosaria, d'Orb.
Verneuilina [*Guembelina*] *polystropha*, Rss. sp.
Gaudryina pupoides, d'Orb.
Gaudryina scabra, Brady.
Gaudryina siphonella, Rss.
Vaginulina legumen, L. sp.
Marginulina costata, Batsch sp.
Marginulina glabra, d'Orb.
Cristellaria crepidula, F. and M. sp.
Cristellaria gibba, d'Orb.
Anomalina ammonoides, Rss. sp.
Pulvinulina elegans, d'Orb. sp.

At Hergott (two bores) the following species were noted :—

Hyperammina vagans, Brady.
Reophax ampullacea, Brady.
Reophax difflugiformis, Brady.
Reophax fusiformis, Will. sp.
Reophax scorpiurus, Montf. sp.
Haplophragmium agglutinans, d'Orb. sp.
Haplophragmium aequale, Roemer. sp,
Haplophragmium glomeratum, Brady.
Haplophragmium canariense, d'Orb. sp.
Haplophragmium australe, Howchin.
Placopsilina cenomana, d'Orb.
Thurammina compressa, Brady.
Ammodiscus incertus, d'Orb. sp.
Bigenerina digitata, d'Orb.
Bigenerina nodosaria, d'Orb.
Verneuilina [*Guembelina*] *polystropha*, Rss. sp.
Gaudryina pupoides, d'Orb.
Gaudryina siphonella, Rss.
Lagena laevis, Mont. sp.
Nodosaria communis, d'Orb.

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* Trans. R. Soc., S. Austr., 1895, pp. 198 and 200. pl. X.

Nodosaria farcimen, Soldani.
Nodosaria pauperata, d'Orb.
Nodosaria radicula, L. sp.
Nodosaria soluta, Rss.
Nodosaria subtertenuata, Schwager.
Lingulina carinata, d'Orb.
Frondicularia complanata, Defr.
Frondicularia sp.
Vaginulina legumen, L. sp.
Vaginulina linearis, Mont. sp.
Marginulina costata, Batsch sp.
Marginulina glabra, d'Orb.
Cristellaria acutauricularis, F. and M. sp.
Cristellaria cassis, F. and M. sp.
Cristellaria crepidula, F. and M. sp.
Cristellaria gibba, d'Orb.
Cristellaria rotulata, Lam. sp.
Cristellaria schloenbachi, Rss.
Polymorphina angusta, Egger.
Polymorphina lactea, W. and J. sp.
Polymorphina rotundata, Born.
Spirillina ? vivipara, Ehr.
Spirillina margaritifera, Brady.
Patellina jonesi, Howchin.
Discorbina vilardeboana, d'Orb. sp.
Anomalina ammonoides, Rss. sp.
Truncatulina lobatula, W. and J. sp.
Pulvinulina elegans, d'Orb. sp.
? *Amphistegina lessonii*, d'Orb.

From Mirrabuckinna, about 20 miles N. of the head of Lake Torrens, the foraminifera noted were :—

Reophax fusiformis, Will. sp.
Reophax scorpiurus, Montfort.
Haplophragmium agglutinans, d'Orb. sp.
Haplophragmium canariense, d'Orb. sp.
Sigmoïlina celata, Costa sp.

From William Creek, about 125 miles N.W. of Hergott were found :—

Haplophragmium canariense, d'Orb. sp.
Gaudryina siphonella, Rss.
Vaginulina legumen, L. sp.
Marginulina glabra, d'Orb.
Cristellaria gibba, d'Orb.

From the Wilcannia Bore :—

Bigenerina nodosaria, d'Orb.

From the Rolling Downs Formation, of Wollumbilla, Queensland, Chas. Moore noted * nine species of foraminifera, four of which are common to the Cretaceous of Central Australia. Moore's list is as follows :—

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* Australian Mesozoic Geology and Palæontology. Quart. Journ. Geol. Soc., Vol. XXVI., 1870, pp. 239 and 242.

Nodosaria communis, d'Orb.
Vaginulina striata, d'Orb.
Cristellaria acutauricularis, F. and M. sp.
Cristellaria acutauricularis var. *longicostata*, Moore (probably *C. costata*, F. and M. sp.).
Cristellaria cultrata, var. *radiata*, Moore (probably *C. subalata*, Rss.).
Polymorphina lactea, W. and J. sp.
Polymorphina gibba, d'Orb.
Truncatulina lobatula, W. and J. sp.
Truncatulina ungeriana, d'Orb. sp.

GENERAL REMARKS ON THE FORAMINIFERAL FAUNA OF GINGIN.

The most striking generic components of this foraminiferal fauna are *Nodosaria*, *Frondicularia*, and *Cristellaria*. They are the most abundant types, and, judging from recent soundings in which they occur, indicate a moderately deep sea with warm temperate conditions. Pelagic forms like *Globigerina* and *Sphaeroidina* and the thin-shelled *Pulvinulinae* are not so strongly represented that they point to the existence at that time and place of an open ocean, but rather lead one to assume that the Cretaceous seas of the Australian area where these deposits were laid down, were of the nature of deep gulfs running into the continent.

The species and varieties of foraminifera from Gingin here recorded total 134. They are generically comprised as follows :—

	spp.		spp.
Spiroloculina ..	2	*Nodosaria*	21
Miliolina	2	*Frondicularia* ..	17
Massilina	1	*Marginulina* ..	3
Rhizammina ..	1	*Vaginulina* ..	3
Haplophragmium ..	1	*Cristellaria*	25
Placopsilina ..	2	*Flabellina*	2
Haplostiche ..	1	*Polymorphina* ..	5
Ammodiscus ..	2	*Sagraina*	3
Textularia	4	*Ramulina*	1
Verneuilina ..	1	*Vitriwebbina* ..	1
Bigenerina ..	1	*Globigerina* ..	6
Spiroplecta ..	3	*Sphaeroidina* ..	1
Guembelina ..	3	*Discorbina*	1
Gaudryina	2	*Truncatulina* ..	4
Clavulina	1	*Anomalina*	1
Bulimina	1	*Pulvinulina* ..	3
Bolivina	1	*Rotalia*	3
Lagena	4	*Nonionina*	1

Of the total number in this fauna, about 59 species are restricted to the Cretaceous in other parts, chiefly in Europe. As to the question of the particular horizon in the Cretaceous system which these foraminifera denote, it may be pointed out that a fairly large number of the species have never been recorded elsewhere except from the Gault (Albian or lower part of the Upper Cretaceous); whilst some, like *Guembelina globulosa*, are Senonian in aspect. On the whole, however, the fauna is decidedly of Albian *cum* Cenomanian relationship, and not Aptian or Lower Cretaceous.

THE FORAMINIFERA.

Fam. MILIOLIDÆ.

Sub-fam. Miliolininæ.

Genus Spiroloculina, *d'Orbigny.*

Spiroloculina (?) grata, *Terquem.*

Spiroloculina (?) *grata*, Terq. Howchin, 1907,* p. 39.

This species, recorded with reservation by Mr. Howchin, was represented by a fragment only. I have not met with it during the present examination of the material.

Spiroloculina asperula, *Karrer.*

(Plate I., fig. 1.)

Spiroloculina asperula, Karrer, 1868, p. 136, pl. I., fig. 10. Chapman, 1891, p. 573, pl. IX., fig. 4. Howchin, 1907, p. 39.

Several examples occur in these washings, some exactly matching the Gault specimens found by the author at Folkestone. It is also a Miocene and living species. Howchin notes it as a common form in the Gingin Chalk.

Genus Miliolina, *Williamson.*

Miliolina oblonga, *Montagu, sp.*

Miliolina oblonga, Mont. sp. Howchin, 1907, p. 39.

This species was recorded as rare in the Gingin Chalk by Mr. Howchin. It was not met with in the present sample of washings.

Miliolina venusta, *Karrer sp.*

(Plate I., fig. 2, pl. XII., fig. 112.)

Quinqueloculina venusta, Karrer, 1868, p. 147, pl. II., fig. 6.
Miliolina venusta, Karrer sp. Chapman, 1891, p. 573, pl. IX., figs. 5*a*, *b* (non 6). Idem, 1899, p. 50.

This species was common in the upper zones of the Gault at Folkestone; and in the Cambridge Greensand, a derivative bed equivalent to the Gault. It is also an Eocene and Miocene fossil, and occurs in recent soundings in deep water.

Several specimens were found in the Gingin Chalk exactly resembling those from the English Gault.

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* For full references *see* bibliography at end.

GENUS MASSILINA, *Schlumberger.*

Massilina ginginensis, *sp. nov.*,

(Plate I., fig. 3.)

(?) *Miliolina venusta*, Karrer sp. Chapman, 1891, p. 573, pl. IX., fig. 6.

Description.—Test broadly ovate, depressed, with a prominent central quinqueloculine series of chambers surrounded by planulate and crescentic biserial chambers. Length, ·757mm. ; width, ·6mm.

Observations.—This foraminifer is probably the same as that figured as a broad variety of *M. venusta* by the writer, from the Gault of Folkestone. It is a more compact shell, with thicker periphery, than *M. secans.*

FAM. ASTRORHIZIDÆ.

SUB-FAM. RHABDAMMININÆ.

GENUS RHIZAMMINA, *Brady.*

Rhizammina indivisa, *Brady.*

(Plate I., fig. 4.)

Rhizammina indivisa, Brady, 1884, p. 277, pl. XXIX, figs. 5–7. Chapman, 1898, pl. 11, p. II., fig. 4. Egger, 1899, p. 15, pl. II., figs. 17–19.

The writer has previously found this species in the Gault of Folkestone and the Chalk-marl of Charing, both in Kent, England ; whilst Egger recorded it from the Chalk-marl of Bavaria. It occurs living in seas of moderate depth.

One specimen.

FAM. LITUOLIDÆ.

SUB-FAM. LITUOLINÆ.

GENUS HAPLOPHRAGMIUM, *Reuss.*

Haplophragmium agglutinans, *d'Orbigny sp.*

(Plate II., fig. 10.)

Spirolina agglutinans, d'Orbigny, 1846, p. 137, pl. VII., figs. 10–12.
Haplophragmium agglutinans, d'Orb. sp., Chapman, 1892, p. 324, pl. V., fig. 14. Egger, 1899, p. 138, pl. I., figs. 38–41, 47, 48.

This species is as old as the Carboniferous, and ranges upwards through the Lias, the Upper Cretaceous (Gault), and Miocene deposits to the present day.

The Gingin specimens closely resemble the small varietal form with high chambers found in the Folkestone Gault by the writer. The specimens figured by Egger from the Chalk-marl of the Upper Bavarian Alps are also closely comparable to the present one.

GENUS PLACOPSILINA, *d'Orbigny.*

Placopsilina vesicularis, *Brady.*

Placopsilina vesicularis, Brady, Howchin, 1907, p. 39.

This species was noted by Mr. Howchin from the Gingin Chalk, and he also remarked its occurrence in the Gault and in the living condition.

Placopsilina cenomana, *d'Orbigny.*

(Plate I., fig. 5.)

Placopsilina cenomana, d'Orbigny, Reuss, 1854, p. 71, pl. XXVIII., figs. 4, 5. Chapman, 1892, p. 324, pl. VI., fig. 4.
Lituola cenomana, d'Orb. sp., Perner, 1892, p. 52, pl. II., figs. 1–6 ; pl. IV., fig. 15. Egger, 1899, p. 136, pl. III., figs. 21, 22.
Placopsilina cenomana, d'Orb., Chapman, 1899, p. 53.

This well-known Cretaceous fossil has been recorded from the Folkestone Gault and from the Bavarian Chalk-marl, as well as from Jurassic beds. Perner obtained it from the Cenomanian of Bohemia. It is a shallow water form in recent deposits.

The figured specimen is typical of the species, and is one of several found in the Gingin Chalk.

GENUS HAPLOSTICHE, *Reuss.*

Haplostiche soldanii, *Jones and Parker sp.*

(Plate I., fig. 6.)

Lituola soldanii, Jones and Parker, 1860, p. 307, No. 184.
Haplostiche soldanii, J. and P. sp., Brady, 1884, p. 318, pl. XXXII., figs. 12–18. Egger, 1899, p. 18, pl. III., figs. 12, 13 ; pl. XXII., figs. 29, 30.

As a Tertiary fossil this species is well distributed, but until Egger's discovery of it in the Chalk-marl of the Upper Bavarian Alps, the records did not date earlier than the Miocene.

In its short, subglobular habit the present specimen approaches *H. sherborni* of the English Gault.* In the living state it is usually dredged from moderate depths in low latitudes.

SUB-FAM. TROCHAMMININÆ.

GENUS AMMODISCUS, *Reuss.*

Ammodiscus incertus, *d'Orbigny* sp.

(Plate I., fig. 7.)

Operculina incerta, d'Orbigny, 1839, p. 71, pl. VI., figs. 16, 17.
Ammodiscus incertus, d'Orb. sp., Brady, 1884, p. 330, pl. XXXVIII., figs. 1–3.
Cornuspira foliacea, Philippi sp. Chapman, 1891, p. 575, pl. IX., figs. 13*a*, *b*.

This species has a wide distribution as a living form. In the fossil condition it dates from the Silurian epoch. The apparently porcellaneous *Cornuspiræ* of the Folkestone Gault were found to be arenaceous, and hence the correction as given above. Very rare in the present sample.

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* Chapman, Journ. Roy. Micr. Soc., Lond., 1892, p. 325, pl. VI., figs. 6–8.

Ammodiscus gaultinus, *Berthelin.*

(Plate I., fig. 8.)

Ammodiscus gaultinus, Berthelin, 1880, p. 19, pl. I., figs. 3*a*,
Egger, 1899, p. 16, pl. I., figs. 1, 3, 8, 9, 30, 31.

This species was originally described by Berthelin from th Albian Gault clays of Montcley, France, and has since been recorde from the Chalk-marl of the Upper Bavarian Alps by Dr. Egger Probably the form described under *Ophthalmidium tumidulum* from the Folkestone Gault, by the writer, should be referred to th above species.

Only one specimen found.

FAM. TEXTULARIIDÆ

SUB-FAM. TEXTULARIINÆ.

GENUS TEXTULARIA, *Defrance.*

Textularia turris, *d'Orbigny.*

(Plate I., fig. 9.)

Textularia turris, d'Orbigny, 1840, p. 46, pl. IV., figs. 27, 28. Brady, 1884, p. 366, pl. XLIV., figs. 4, 5. Chapman, 1892, p. 328, pl. VI., fig. 19. Egger, 1899, p. 29, pl. XIV., fig. 29.

A typical Cretaceous species, occurring in both the lower and the upper divisions of that series in Europe.

This species was recorded by Mr. Howchin as rare in the Gingin Chalk. In the present sample several fine specimens were found, some of large size.

Textularia trochus, *d'Orbigny.*

Textularia trochus, d'Orbigny, Howchin, 1907, p. 40.

Mr. Howchin found several examples of this form, including one fine specimen. None occurred in my sample.

Textularia gibbosa, *d'Orbigny.*

(Plate II., fig. 11.)

Textularia gibbosa, d'Orb., Chapman, 1907, p. 25, pl. III., fig. 54. Howchin, 1907, p. 40.

Mr. Howchin remarks on the species as follows :—

> "Numerous examples referable to this type occur and show much variation as to size, some being small and stunted, others longer and tapering. The last two chambers, in all cases, are larger and more inflated than the others. In a few instances the aboral extremity is acuminate."

Several examples were found by the writer, all of which were small.

T. gibbosa is usually a Tertiary fossil, but has also been recorded from the Carboniferous of England, Scotland, Belgium, and Russia. It occurs in the living condition in the Mediterranean and elsewhere.

Textularia gramen, *d'Orbigny.*

(Plate II., fig. 12.)

Textularia gramen, d'Orbigny, 1846, p' 248, pl. XV., figs. 4–6. Chapman, 1892, p. 328, pl. VI., figs. 17*a*, *b*. Egger 1899, p. 25, pl. II., figs. 27, 28.

T. gramen is a well-known fossil in the Gault and Chalk-marl deposits of Europe, and its range extends through the Tertiaries to recent soundings.

One specimen found.

GENUS VERNEUILINA, *d'Orbigny.*

Verneuilina spinulosa, *Reuss.*

Verneuilina spinulosa, Reuss, Howchin, 1907, p. 40.

Howchin records one example from the Gingin Chalk. It appears to be absent from my sample.

GENUS BIGENERINA, *d'Orbigny.*

Bigenerina compressiuscula, *sp. nov.*

(Plate II., figs. 13, 14.)

Description.—Test elongate-ovate, compressed. Chambers at aboral end irregularly textularian with the extremity sometimes acuminate, afterwards uniserial, short and wide. Aperture prolonged, tubular. Texture moderately coarsely arenaceous, but with smooth surface.

Length.—2·1 mm. ; greatest width, ·074 mm.

Observations.—This species reminds one of *Spiroplecta prælonga,* Reuss sp., but that the later segments are uniserial ; the examples found being fairly constant in this last respect.

Bigenerina arenacea, Bagg,* is related to this form, but has a broader shell and is less flattened in contour ; whilst its biserial commencement is more regular than in ours.

Common in the sample from Gingin.

GENUS SPIROPLECTA, *Ehrenberg.*

Spiroplecta sagittula, *Defrance sp.*

(Plate II., fig. 15.)

Textularia sagittula, Defr., Chapman, 1892, p. 328, pl. VI., fig. 16. Egger, 1899, p. 26, pl. XIV., figs. 44, 45. Howchin, 1907, p. 40.

Spiroplecta sagittula, Defr. sp., Chapman, 1907, p. 27, pl. III., figs. 58, 59.

Mr. Howchin records some small but well-formed specimens from the Gingin Chalk.

The figured specimen represents the only example found in the material submitted, and is shorter and broader than the living forms. The specimen figured from the Gault is more acute aborally, as is also the Bavarian Chalk-marl specimen figured by Egger.

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* Bagg. Proc. U.S. Nat. Mus., vol. 34, 1908, p. 132, pl. V., fig. 46. Cushman, Bull. 71, U.S. Nat. Mus., 1911, p. 29, Text fig. 50A, B.

Spiroplecta anceps, *Reuss sp.*

(Plate II., fig. 16 ; pl. XII., fig. 114.)

Textularia anceps, Reuss, 1845–6, pt. I., p. 39, pl. VIII., fig. 79 ; pl. XIII., fig. 2.

Spiroplecta anceps, Reuss sp., Chapman, 1892[2], p. 751, pl. XI., fig. 6.

Textularia anceps, Reuss, Egger, 1899, p. 25, pl. XXIV., figs. 35, 36.

This species resembles *S. carinata*, d'Orb. sp. but has a shorter and broader test with fewer chambers.

It is of frequent occurrence in the present sample, and closely resembles the English Gault specimens. Egger's shells from the Bavarian Chalk-marl are more attenuated in outline.

Spiroplecta prælonga, Reuss. sp.

(Plate XII., fig. 113.)

Textularia prœlonga, Reuss, 1845–6, pt. I., p. 39, pl. XII., fig. 14.

Spiroplecta prœlonga, Rss. sp., Chapman, 1892[2], p. 3, pl. XI., fig. 5.

Textularia prœlonga, Rss., Chapman, 1894[4], p. 698.

The figured specimen from the present series is a short form of the above species which has been previously noted from the Lower Greensand (Aptian) of Surrey, the Gault of Folkestone, the Red Chalk of East Anglia and the Plänermergel of Bohemia.

One example from the Gingin Chalk.

GENUS GUEMBELINA, *Egger.*

Guembelina globulosa, *Ehrenberg sp.*

(Plate II., fig. 17.)

Textularia globulosa, Ehrenberg, 1838, p. 135, pl. IV., fig. B., frequens.

Textularia globulosa, Ehrenb., Reuss, 1845–6, pt. I., p. 39, pl. XII., fig. 23.

Guembelina globulosa, Ehr. sp., Egger, 1899, p. 32, pl. XIV., fig. 43.

Textularia globulosa, Ehr., Howchin, 1907, p. 40.

This and the two succeeding species have been placed in the genus *Guembelina* by Egger on account of the distinctive bulimine commencing series of chambers which afterwards takes on the biserial textularian character.

Mr. Howchin records this species as rare from the Gingin Chalk. It is fairly abundant in the finer siftings of my samples.

A very characteristic species of the Upper Chalk of Europe and America.

Guembelina globifera, *Reuss. sp.*

(Plate II., fig. 18.)

Textularia globifera, Reuss, 1860, p. 232, pl. XIII., figs. 7*a*, *b*, 8.

Guembelina globifera, Reuss sp., Egger, 1899, p. 33, pl. XIV., figs. 35, 36, 53–55.

This species is rare in the present sample. It occurred previously in the Chalk-marl of Westphalia and the Upper Bavarian Alps.

Guembelina polystropha, *Reuss sp.*

(Plate II., fig. 19.)

Bulimina polystropha, Reuss, 1845–6, pt. II., p. 109, pl. XXIV., fig. 53.

Gümbelina polystropha, Reuss sp., Egger, 1899, p. 34, pl. XIV., figs. 31–34, 40.

Verneuilina polystropha, Rss. sp., Howchin, 1907, p. 40.

Mr. Howchin records this species as occurring in considerable numbers. It does not appear to be common in the present sample. It is distinguished from the two preceding species by the much longer test and strongly twisted aboral extremity. The figured specimen is an elongate variety.

A common Chalk-marl species. The recent specimens assigned to this form seem to belong to a distinct species.

GENUS GAUDRYINA, *d'Orbigny.*

Gaudryina pupoides, *d'Orbigny.*

(Plate II., fig. 20.)

Gaudryina pupoides, d'Orbigny, 1840, p. 44, pl. IV., figs. 22–24. Chapman, 1892^{2}, p. 752, pl. XI., figs. 8*a*, *b*. Idem, 1899, p. 59, Egger, 1899, p. 37, pl. IV., figs. 19, 20.

This familiar Gault and Chalk-marl species is fairly frequent in the present sample. The recent specimens usually assigned to *G. pupoides* have been lately renamed by J. Cushman* on account of the more tapering and aborally pointed test of the recent form.

Gaudryina rugosa, *d'Orbigny.*

(Plate II., fig. 21.)

Gaudryina rugosa, d'Orbigny, 1840, p. 44, pl. IV., figs. 20, 21. Reuss, 1845–6, pt. I., p. 38, pl. XII., figs. 15, 24. Egger, 1899. p. 37, pl. IV., figs. 14, 15.

This species is typically Cretaceous, but also ranges through the Tertiary and later formed deposits. The Cretaceous form usually has a smaller triserial commencement than in living examples.

Very common in the present washings from Gingin.

Clavulina communis, *d'Orbigny.*

(Plate II., fig. 22.)

Clavulina communis, d'Orbigny, 1826, p. 268. Idem, 1846, p. 196, pl. XII., figs. 1, 2. Cushman, 1911, p. 73, text-figs. 115–117.

This species has hitherto been noted only from Tertiary and recent deposits, commencing its history in the Eocene of the South of France and the London Basin.

Its advent in Cretaceous times in Australia is particularly interesting.

Two typical specimens occur in the present sample from Gingin.

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* *G. bradyi*, Cushman, Mon. Foram., N. Pacific Ocean.—Bull. 71, U.S. Nat. Mus., 1911, p. 67, text. fig. 107, *a–c*.

SUB-FAM. BULIMININÆ.

GENUS BULIMINA, *d'Orbigny.*

Bulimina variabilis, *d'Orbigny.*

(Plate XII., fig. 115.)

Bulimina variabilis, d'Orbigny, 1840, p. 40, pl. IV., figs. 9–12. Reuss, 1845–6, pt. I., p. 37, pl. VIII., figs. 56, 76, 77. Eley, 1859, p. 198, pl. V., fig. 29.

This is a familiar Chalk fossil. It has been recorded from the Chalk-marl and Cenomanian of Bohemia and the Chalk of France and England.

One specimen from Gingin.

GENUS BOLIVINA, *d'Orbigny.*

Bolivina obsoleta, *Eley sp.*

(Plate XII., fig. 116.)

Textularia obsoleta, Eley, 1859, p. 195, pl. II., fig. 11 ; p. 202, pl. VIII., fig. 11c.

T. quadrilatera, Schwager, 1866, p. 253, pl. VII., fig. 103. Brady, 1884, p. 358, pl. XLII., figs. 8–12.

The Cretaceous specimens have a narrower habit of growth than the Pliocene or recent ; otherwise there is no difference between them. Eley's specimens came from the English Chalk.

Common in the fine washings of Gingin.

FAM. LAGENIDÆ.

SUB-FAM. LAGENINÆ.

GENUS LAGENA, *Walker and Boys.*

Lagena globosa, *Montagu sp.*

(Plate III., fig. 23.)

Lagena globosa, Montagu sp., Brady, 1884, p. 45, pl. LVI., figs. 1–3. Chapman, 1893, p. 579, pl. VIII., figs. 1*a*, *b* Egger, 1899, p. 102, pl. V., fig. 3. Howchin, 1907, p. 40 (*L. globulosa*).

The range of typical forms of this species extends from the Lias to recent.

This species is recorded by Howchin as rare. In the present sample it occurs with some frequency.

Lagena apiculata, *Reuss sp.*

(Plate III., fig. 24.)

Oolina apiculata, Reuss, 1851, p. 22, pl. I., fig. I.

Lagena apiculata, Reuss sp., Burrows, Sherborn and Bailey, 1890, p. 555, pl. IX., figs, 6, 7, 9–11. Chapman, 1893, p. 581, pl. VIII., figs. 2*a*, *b*, 3*a*, *b*. Egger, 1899, p. 103, pl. V., fig. 32.

L. apiculata is a very characteristic species in Cretaceous deposits in Europe ; it also occurs sporadically throughout the Tertiaries, and is still found living.

Three typical specimens occurred in the Gingin Chalk.

Lagena aspera, *Reuss.*

(Plate III., fig. 25.)

Lagena aspera, Reuss, 1861, p. 305, pl. I., fig. 5. Chapman, 1893, p. 582, pl. VIII., fig. 8. Egger, 1899, p. 106, pl. V., fig. 10.

This species has an extensive range, from the Lias to recent. The specimen here figured has the usual roughened or papillate surface, whilst the form of the test is subglobose and slightly flattened.

Only one specimen was found in the Gingin Chalk.

Lagena hispida, *Reuss.*

Lagena hispida, Reuss, Howchin, 1907, p. 40.

Mr. Howchin records a specimen of this form having a "Test globular and hispid, without long neck."

This species did not occur in the present sample.

SUB-FAM NODOSARIINÆ.

GENUS NODOSARIA, *Lamarck.*

SUB-GENUS DENTALINA, *d'Orbigny.*

Nodosaria (Dentalina) pauperata, *d'Orbigny.*

(Plate III., fig. 26.)

Dentalina pauperata, d'Orbigny, 1846, p. 46, pl. I., figs. 57, 58. Bornemann, 1855, vol. VII., p. 324, pl. XIII., fig. 7.

Nodosaria (D.) pauperata, d'Orb., Chapman, 1893, p. 588, pl. VIII. fig. 32. Egger, 1899, p. 60, pl. VI., fig. 20.

This species ranges from the Lias to recent soundings. It is of frequent occurrence in the Chalk and Gault. Very rare in the present series.

Nodosaria (D.) distincta, *Reuss.*

(Plate III., fig. 27.)

Dentalina distincta, Reuss, 1860, p. 184, pl. II., fig. 5.

Previously described from the Chalk of Westphalia. The species resembles a short, irregularly chambered form of *N.* (*D.*) *farcimen*, Soldani.

Several specimens occur in the Gingin Chalk.

Nodosaria (D.) soluta, *Reuss.*

(Plate III., fig. 28.)

Dentalina soluta, Reuss, 1851, p. 60, pl. III., figs. 4*a*, *b*

Nodosaria (D.) soluta, Reuss, Chapman, 1893, p. 587, pl. VIII., fig. 26.

Nodosaria soluta, Bornemann, Egger, 1899, p. 59, pl. VI., fig. 23; pl. VII., fig. 3.

N. soluta, Rss., Howchin, 1907, p. 41.

This species ranges from the Cretaceous to recent. The Chalk specimens as a rule have the chambers more closely conjoined.

Mr. Howchin records this species from Gingin.

It is quite a common form in the present sample.

Nodosaria (D.) soluta, var. discrepans, *Reuss.*

(Plate III., fig. 29.)

Dentalina discrepans, Reuss, 1860, p. 184, pl. III., fig. 7.
Nodosaria (*D.*) *discrepans*, Reuss, Chapman, 1893, p. 587, pl. VIII., fig. 27.
Nodosaria discrepans, Rss., Egger, 1899, p. 69, pl. VII., fig. 19.

This variety appears to be confined to the Cretaceous, having occurred in the Gault of Folkestone, and the Chalk of Westphalia and the Bavarian Alps.

A few examples from the Gingin Chalk.

Nodosaria (D.) annulata, *Reuss.*

(Plate III., figs. 30, 31.)

Nodosaria annulata, Reuss, 1844, p. 210. Idem, 1845–6, pt. I., p. 27, pl. VIII., figs. 4 and 67 ; pl. XIII., fig. 21.
Dentalina annulata, Reuss, 1851, p. 26, pl. I., fig. 13.
Nodosaria annulata, Reuss, Egger, 1899, p. 63., pl. VII., figs. 9–11.

This species is perhaps the most abundant of the *Nodosariæ* in the Gingin Chalk. It is as variable as it is common. The earlier chambers are closely cateniferous, and towards the end of the series become more separate and inflated as in *N.* (*D.*) *soluta*. The short, inflated varieties resemble *Nodosaria limbata*, d'Orbigny, from the Chalk of the Paris Basin and elsewhere.

N. (*D.*) *annulata* is typically Cretaceous but has also occurred in the Tertiaries of Italy.

Nodosaria (D.) communis, *d'Orbigny.*

(Plate III., fig. 32.)

Dentalina communis, d'Orbigny, 1840, p. 13, pl. I., fig. 4.
Nodosaria (*D.*) *communis*, d'Orb., Reuss, 1845–6, pt. I., p. 28., pl. XII., fig. 21. Chapman, 1893, p. 590, pl. IX., fig. 1.
Nodosaria communis, d'Orb., Egger, 1899, p. 65, pl. VI., fig. 4.

This species has a wide geological range and is always fairly common in Cretaceous deposits.

Several typical specimens occur in the Gingin Chalk.

Nodosaria (D.) consobrina, *d'Orbigny*, var. emaciata, *Reuss.*

(Plate III., fig. 33.)

Dentalina emaciata, *Reuss*, 1851, p. 63, pl. III., fig. 9.
Nodosaria (*D.*) *consobrina*, var. *emaciata*, Rss., Brady, 1884, p. 502, pl. LXII., figs. 25, 26. Howchin, 1907, p. 41.

The long attenuated form of *N.* (*D.*) *consobrina* is fairly well distributed through the Tertiaries and recent deposits. It is interesting to find it in the Australian Cretaceous, which occurrence thereby extends its range.

Mr. Howchin records this variety as common in the Gingin Chalk. Several specimens were found in the present sample.

Nodosaria (Dentalina) legumen, *Reuss.*

(Plate XII., fig. 119.)

Nodosaria (Dentalina) legumen, Reuss, 1845–6, pt. I., p. 28, pl. XIII., figs. 23, 24.

Nodosaria legumen, Reuss, 1860, p. 187, pl. III., fig. 5. Egger, 1899, p. 54, pl. V., figs. 36–39 ; pl. VI., figs. 1–3.

The solitary specimen occurring in the present series is a short, few-chambered form similar to some figured by Dr. Egger from the Bavarian Chalk-marl. It is a well-known species in the Gault faunas of France and England, and the Chalk-marl of Germany and Poland.

Nodosaria (D.) lorneiana, *d'Orbigny.*

(Plate IV., fig. 34.)

Dentalina lorneiana, d'Orbigny, 1840, p. 14, pl. I., figs. 8, 9.

Nodosaria lorneiana, d'Orbigny, Reuss, 1845–6, pt. I., p. 27, pl. VIII., fig. 5.

Nodosaria (D.) lorneiana, d'Orb., Chapman, 1893, p. 588, pl. VIII., figs. 30, 31. Egger, 1899, p. 56, pl. VI., figs. 21, 22.

This is a typical Cretaceous form, resembling a *N.* (*D.*) *consobrina* with longish elliptical chambers scarcely increasing in size with growth.

Recorded from the Gault and Chalk of England, and from the Chalk of Aix la Chapelle, Rügen, Bavaria, and Bohemia.

Common in the Gingin Chalk.

Nodosaria (D.) filiformis, *d'Orbigny.*

(Plate IV., fig. 35.)

Nodosaria filiformis, d'Orbigny, 1826, p. 253, No. 14. Reuss, 1845–6, pl. I., fig. 28 ; pl. XII., fig. 28.

Dentalina filiformis, Reuss, 1860, p. 188, pl. III., fig. 8.

Nodosaria (D.) filiformis, d'Orb., Brady, 1884, p. 500, pl. LXIII., figs. 3–5.

Nodosaria filiformis, Reuss, Egger, 1899, p. 67, pl. VI., figs. 28–30.

The species range from the Lias through the Cretaceous and Tertiaries to recent deposits, where it is found in moderately deep water. Reuss' specimens were found in the Chalk of Bohemia and Westphalia, whilst Egger found it in the Bavarian Chalk-marl.

Very rare in the Gingin Chalk.

Nodosaria (D.) retrorsa, *Reuss sp.*

(Plate IV., fig. 36.)

Dentalina retrorsa, Reuss, 1864, p. 46, pl. III., fig. 27.

Nodosaria (D.) retrorsa, Reuss, Brady, 1884, p. 507, pl. LXIII., fig. 7.

Nodosaria retrorsa, Reuss, Egger, 1899, p. 81, pl. IX., fig. 25.

This species, which was earlier known as an Oligocene fossil, and a still-living form (off the Ki Islands, 580 fathoms), has more lately been described from the Chalk of Bavaria by Dr. Egger.

Our specimens are typical, and the species is not uncommon in the Gingin Chalk.

Nodosaria (D.) intercellularis, *Brady.*

(Plate IV., fig. 37.)

Nodosaria (*D.*) *intercellularis*, Brady, 1884, p. 515, pl. LXV., fig
1–4. Chapman 1893, p. 591, pl. IX., fig. 8.

It is of much interest to find this species, originally found livi off Bermuda at 435 fathoms and which was subsequently obtain by the writer from the Gault of Folkestone, in the West Australi Cretaceous.

One typical specimen from Gingin.

Nodosaria (D.) costellata, *Reuss.*

(Plate IV., fig. 38.)

Nodosaria costellata, Reuss, 1845–6, pt. I., p. 27, pl. XIII., fig. 18
Nodosaria (*D.*) *costellata*, Rss., Chapman, 1893, p. 590, pl. IX
fig. 3.
Nodosaria costellata, Rss., Egger, 1899, p. 74, pl. VIII., figs. 13, 1

This is a distinctly Cretaceous form, occurring in the Pläne mergel of Bohemia, the Chalk-marl of the Bavarian Alps, and t Gault of Folkestone.

The figured specimen has the surface entirely costate, b the ribs are slightly stronger on the sutures. As a rule the cost do not extend beyond the constricted area between the chamber

One specimen found in the present sample.

Nodosaria (D.) obliqua, *Linné sp.*

(Plate IV., fig. 39.)

Nodosaria obliqua, L. sp., Brady, 1884, p. 513, pl. LXIV., figs. 20–2
Howchin, 1907, p. 41.

This typically ornamented and central type-form of the costat nodosarines is found in all fossiliferous deposits dating from t Permian to the present day.

Specimens comparable with that figured are not uncommon the present sample from Gingin. Mr. Howchin records one spec men from the same deposit.

Nodosaria (D.) sulcata, *Nilsson.*

(Plate IV., fig. 40.)

Nodosaria sulcata, Nilsson, 1827, p. 8, pl. IX., fig. 19. Reus
1845–6, pt. I., p. 26, pl. XIII., fig. 17.
Nodosaria (*D.*) *sulcata*, Nilsson, Sherborn and Chapman, 188
p. 486, pl. XI., fig. 24.
Nodosaria sulcata, Nilsson, Egger, 1889, p. 75, pl. VIII., fig. 24

This is one of the strongly sulcate dentaline forms in whic the costæ are not oblique as in *N.* (*D.*) *obliqua*. It is typicall Cretaceous, but has also occurred in certain Tertiary deposits, a the London Clay. Amongst Cretaceous localities we may mentio the Paris Basin, Rügen, Lemberg, Bavaria, and Bohemia.

Not uncommon in the Gingin Chalk.

Nodosaria (D.) paupercula, *Reuss.*

(Plate IV., fig. 41.)

Nodosaria paupercula, Reuss, 1845–6, pt. I., p. 26, pl. XII., fig. 12.
Dentalina paupercula, Rss., Berthelin, 1880, p. 43, pl. II., figs. 17*a*, *b*.
Nodosaria (*D.*) *paupercula*, Rss., Chapman, 1893, p. 593, pl. IX., figs. 13, 14.
N. paupercula, Rss., Egger, 1899, p. 72, pl. VIII., fig. 7.

This is a rather common species in the Gingin Chalk.

The specimens agree precisely with those from the English and French Gault, and the Chalk of Bavaria, Saxony, and the Isle of Rügen.

Nodosaria subtertenuata, *Schwager.*

(Plate XII., fig. 117.)

Nodosaria subtertenuata, Schwager, 1866, p. 235, pl. VI., fig. 74. Brady, 1884, p. 507, pl. LXII., figs. 7, 8. Howchin, 1894, p. 364.

This species was originally recorded from the Pliocene of Kar-Nicobar, and Brady subsequently found it in recent soundings off the Ki Islands near Japan in 129 fathoms. Since then Mr. Howchin has discovered it in the Cretaceous foraminiferal deposits of Hergott township, Bore No. 2. It is therefore extremely interesting to find it in the present washings from Gingin.

Not uncommon ; specimens quite typical.

Nodosaria vertebralis, *Batsch sp.*

Nodosaria vertebralis, Batsch sp., Howchin, 1907, p. 41.

Mr. Howchin records one or two fragments from the Gingin Chalk. It has previously occurred in the fossil state in Tertiary beds, and is well known as a recent form. It was not met with in my sample.

Nodosaria obscura, *Reuss.*

(Plate IV., fig. 42.)

Nodosaria obscura, Reuss, 1845–6, pt. I., p. 26, pl. XIII., figs. 7–9. Burrows, Sherborn, and Bailey, 1890, p. 557, pl. IX., fig. 24.
Nodosaria (*D.*) *obscura*, Reuss, Chapman, 1893, p. 593, pl. IX., fig. 16.
Nodosaria obscura, Reuss, Egger, 1899, p. 75, pl. XXIV., fig. 23. Heron-Allen and Earland, 1910, p. 418, pl. VII., fig. 7.

This species differs from typical specimens of *N. raphanus* in the more irregular growth of the test and the obscurely marked septa. It is a common Chalk species.

Moderately common in the Gingin Chalk.

Nodosaria prismatica, *Reuss.*

(Plate IV., fig. 43.)

Nodosaria prismatica, Reuss, 1860, p. 180, pl. II., fig. 2. Idem, 1862, p. 36, pl. II., fig. 7. Burrows, Sherborn, and Bailey, 1890, p. 557, pl. IX., figs. 25*a*, *b*. Chapman, 1893, p. 594, pl. IX., fig. 21. Egger, 1899, p. 77, pl. VIII., figs. 5, 8*a*, *b*.

This is a distinct variety of the *N. raphanus* type, recognised by its narrow rod-like test and evenly spaced costae, which latter feature gives it a polygonal outline in transverse section.

It is moderately common in the Gingin Chalk.

Nodosaria perpusilla, *Chapman.*

(Plate XII., fig. 118.)

Nodosaria perpusilla, Chapman, 1893, p. 591, pl. IX., fig. 6.

This is a very small, slender and finely costate modification of the *N. raphanus* type, and was first described from the Gault of Folkestone.

One specimen from Gingin.

GENUS FRONDICULARIA, *Defrance.*

Frondicularia ornata, *d'Orbigny.*

(Plate V., fig. 44.)

Frondicularia ornata, d'Orbigny, 1840, p. 21, pl. I., figs. 37, 38; facsimile in Science Gossip, 1870, p. 82, fig. 92. Reuss, in Geinitz, 1845–6, p. 653, pl. XXIV., fig. 20. Egger, 1899, p. 91, pl. X., figs. 15, 16.

This species is a stoutly built, sparsely chambered form of the *F. archiaciana* type. It is restricted to the Chalk and Chalk-marl, but is not at all common at any locality. D'Orbigny's specimens came from the White Chalk of the Paris Basin, whilst Egger had it from the Chalk-marl of the Upper Bavarian Alps.

Rare in the Gingin Chalk.

Frondicularia archiaciana, *d'Orbigny.*

(Plate V., fig. 45.)

Frondicularia archiaciana, d'Orbigny, 1840, p. 20, pl. I., figs. 34–36; facsimile in Science Gossip, 1870, p. 82, fig. 91. Reuss, 1845-6, pt. I., p. 31, pl. XIII., fig. 39. Eley, 1859, p. 197, pl. IV., fig. 19 (flint cast). Brady, 1884, p. 520, pl. CXIV., fig. 12. Chapman, 1894, p. 155, pl. III., fig. 6. Perner, 1897, p. 69, pl. V., fig. 3. Chapman, 1899, p. 304. Egger, 1899, p.87, pl. X., figs. 19, 20.

This typically Cretaceous species has survived to the present day, but in the living condition is almost unique, the "Challenger" obtaining it from only one locality, Raines Islet, Torres Strait at 155 fathoms.

It is not uncommon in the Gault, Greensand, and Chalk of Europe and the British Islands.

Several examples occurred in the Gingin Chalk.

Frondicularia chapmani, *Perner.*

(Plate V., fig. 46.)

Frondicularia chapmani, Perner, 1897, p. 69, pl. IV., fig. 17. Howchin, 1907, p. 41.

This species was originally found in the Bohemian Chalk. It is easily distinguished by the smooth, convex faces and elongate lanceolate form, broadest in the upper third, and with concave and rapidly narrowing sides towards the aboral extremity.

Mr. Howchin records several fragmentary specimens of this form from the Gingin Chalk. It is not uncommon in the present sample, but never quite perfect at the commencement of the test.

Frondicularia lanceola, *Reuss.*

(Plate V., fig. 47.)

Frondicularia lanceola, Reuss, 1860, p. 198, pl. V., fig. 1. Chapman, 1894, p. 157, pl. III., fig. 15. Perner, 1897, p. 67, pl. III., fig. 2. Chapman, 1899, p. 302. Egger, 1899, p. 87, pl. XV., figs. 9, 10.

This species is distinguished by its exceptionally slender proportions, and is uniformly narrow, unlike *F. angusta*, Nilsson, and other similar forms, which broaden considerably in their later growth.

F. lanceola has been met with in the Gault of Folkestone, the Cambridge Greensand (probably a remanié bed of Gault age), the Westphalian Chalk and the Chalk marl of Bavaria.

Typical specimens very common in the Gingin Chalk.

Frondicularia inversa, *Reuss.*

(Plate V., figs. 48, 49.)

Frondicularia inversa, Reuss, 1845–6, pt. I., p. 31, pl. XIII., figs. 15–19. Chapman, 1894, p. 155, pl. III., fig. 8. Perner, 1897, p. 69, pl. IV., figs. 5–8. Egger, 1899, p. 90, pl. X., figs. 3, 4. Chapman, 1899, p. 302.

This is a somewhat broad, subrhomboidal shell with numerous acute chambers and plane surface except for the sutural margins which are narrow and in relief. It is a well known Chalk species and its range extends through the Gault and Chalk in Europe and Great Britain.

Not uncommon in the Gingin Chalk.

Frondicularia apiculata, *Reuss.*

(Plate V., fig. 50.)

Frondicularia apiculata, Reuss, 1845–6, pt. I., p. 30, pl. VIII., fig. 24. Idem, 1860, p. 192, pl. V., fig. 2.

This species resembles *F. archiaciana* in general characters but is not so slender, whilst the chambers are more closely set.

Recorded by Reuss from the Bohemian and Westphalian Chalk. Rare in the Gingin Chalk.

Frondicularia sherborni, *Perner.*

(Plate VI., fig. 51.)

Frondicularia sherborni, Perner, 1897, p. 68, pl. IV., fig. 9.

This species is not unlike *F. intermittens,* Reuss, but the ch bers are not so clearly marked off, and the striæ are finer and m continuous along the length of the test; it is also more elongate t that species.

Not uncommon at Gingin.

Frondicularia marginata, *Reuss.*

(Plate VI., fig. 52.)

Frondicularia marginata, Reuss, 1845–6, pt. I., p. 30, pl. X fig. 9; pt. II., p. 107, pl. XXIV., figs. 39, 40. Idem, 18 p. 193, pl. V., fig. 3.

This species is of the *F. angusta,* Nilsson type, with a c planate and subelongate shell, but having the external marg rim-like.

It was formerly known from the Bohemian and Westphal Chalk.

Several specimens occurred in the Gingin Chalk.

Frondicularia decheni, *Reuss.*

(Plate VI., fig. 53.)

Frondicularia decheni, Reuss, 1860, p. 191, pl. IV., fig. 3. Perne 1897, p. 67, pl. III., fig. 3; pl. V., figs. 6, 15.

A short form of the *F. archiaciana* type, but with alm parallel sides and striated faces.

Known formerly from the Bohemian and Westphalian Chal

Several specimens were found in the Gingin Chalk.

Frondicularia gaultina, *Reuss.*

(Plate V., figs. 54, 55.)

Frondicularia gaultina, Reuss, 1860, p. 194, pl. V., fig. 5. Burrow Sherborn, and Bailey, 1890, p. 558, pl. X., fig. 5. Chapma 1894, p. 155, pl. III., fig. 7. Perner, 1897, p. 69, pl. IV., fig. pl. V., fig. 1. Howchin, 1907, p. 41.

This species is confined to the Gault and Chalk. The sh shows some latitude in variation, but its general characters a summed up as follows:—Rather broadly hastate, equally point at each end; complanate; sutures flush or slightly raised; pri ordial chamber subovate, small to moderately large and inflate By increase of breadth this shell appears to pass into *F. guestphali* Mr. Howchin also records this species from Gingin.

Not uncommon in the Gingin Chalk.

Frondicularia ungeri, *Reuss.*

(Plate VI., fig. 56.)

Frondicularia ungeri, Reuss, 1862, p. 54, pl. IV., figs. 11 a, b. Berthelin, 1880, p. 61, pl. IV. (XXVII.), fig. 4. Chapman, 1894, p. 157, pl. III., fig. 16. Id., 1899, p. 302. Egger, 1899, p. 89, pl. XIII., figs. 10, 11.

This is a short broad form with only three segments. It was previously known from the North German, French and English Gault, as well as the Cambridge Greensand.

Very rare in the Gingin Chalk.

Frondicularia perovata, *Chapman.*

(Plate VI., fig. 57.)

Frondicularia perovata, Chapman, 1894, p. 158, pl. IV., figs. 5*a*, *b*.

This rather handsome species has hitherto been known only from the English Gault. The West Australian specimen here figured does not show the striated surface seen in the English shell but otherwise it is typical.

Very rare in the Gingin Chalk.

Frondicularia guestphalica, *Reuss.*

(Plate VII., fig. 58.)

Frondicularia guestphalica, Reuss, 1860, p. 195, pl. VI., fig. 2. Chapman, 1894, p. 158, pl. IV., fig. 2. Idem, 1899, p. 303.

This broad, complanate form has been found in the Gault of Folkestone, the Cambridge Greensand, and the Chalk of Westphalia.

Not uncommon in the Gingin Chalk.

Frondicularia intermittens, *Reuss.*

(Plate VII., fig. 59.)

Frondicularia intermittens, Reuss, 1865, p. 460 (name only), pl. —., fig. 11. Howchin, 1907, p. 41.

This form is represented by a fair number of specimens in the present sample, that figured being one of the more robust varieties. I am indebted to my friend Mr. Howchin for a tracing of Reuss' original figure. This species has been already recorded by Mr. Howchin from Gingin.

Frequent in my sample of the Gingin Chalk.

Frondicularia cordai, *Reuss.*

(Plate VII., fig. 60.)

Frondicularia cordai, Reuss, 1845–6, pt. I., p. 31, pl. VIII., figs. 26–28 ; pl. XIII., fig. 41 and pt. II., p. 108, pl. XXIV., fig. 38. Chapman, 1894, p. 159, pl. IV., fig. 6. Perner, 1897, p. 69, pl. V., fig. 9. Egger, 1899, p. 90, pl. XIII., fig. 21.

A well known Chalk and Gault species.

Very rare in the Gingin Chalk.

Frondicularia lanceolata, *Perner.*

(Plate VII., fig. 61.)

Frondicularia lanceolata, Perner, 1892, p. 60, pl. VII., figs. 12*a*, *l*
Idem, 1897, p. 67, pl. III., fig. 1 ; pl. IV., fig. 2.

This species is recorded by Perner as common in the Chalk Bohemia.

It may here be noted that a "*Frondicularia lanceolata*" wa described by Costa in 1855,* but this has been shown by Dr. A Silvestri† to be the same as d'Orbigny's *Cristellaria lanceolat* of the Vienna Basin memoir, and therefore Perner's name sti holds good.

Not uncommon in the Gingin Chalk.

Frondicularia angusta, *Nilsson.*

(Plate VII., fig. 62.)

Frondicularia angusta, Nilsson, Reuss, 1845–6, pt. I., p. 29, pl VIII., figs. 13, 14. Idem, 1860, p. 196, pl. IV., fig. 5. Perner, 1897, p. 68, pl. IV., fig. 18 ; pl. V., figs. 4, 8, 11.

This is a thin, complanate form with numerous and narrow chambers, the test being slender at the aboral end and widening rapidly towards the oral extremity. It seems to be a typical Chalk species.

Frequent in the Gingin Chalk.

GENUS MARGINULINA, *d'Orbigny.*

Marginulina costata, *Batsch sp.*

(Plate VII., figs. 63, 64.)

Nautilus (*Orthoceras*) *costatus*, Batsch, 1791, pl. I., figs. 1*a*-*g*.
Marginulina costata, Batsch sp., Brady, 1884, p. 528, pl. LXV., figs. 10–13. Sherborn and Chapman, 1889, p. 487, pl. XI., fig. 28. Howchin, 1907, p. 42.

The shells from Gingin are all uniformly strongly costate, and therefore agree with Batsch's central type. Although search was made for the finely costate and striate varietal form, named by Reuss *M. striatocostata*, and found in the Gault and Chalk of Europe, none was discovered in the present sample. The species has an extensive geological range, from the Lias to recent. One of the specimens figured shows a cristellarian commencement, as in Brady's "Challenger" specimen on plate LXV., fig. 11.

This species has already been noted by Mr. Howchin as moderately common at Gingin. Very abundant in the present sample.

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* Mem. Accad. Sci. Napoli, II., 1855 (1857), p. 372, pl. III., fig. 7.

† Mem. della Pont. Accad. d. Nuovi Lincei, vol. XV., 1898, p. 173.

Marginulina glabra, *d'Orbigny.*

(Plate VII., fig. 65.)

Marginulina glabra, d'Orbigny, 1826, Vol. VII., p. 259, No. 6; Modèle, No. 55. Brady, 1884, p. 527, pl. LXV., figs. 5, 6. Chapman, 1894, p. 160, pl. IV., figs. 11*a*, *b*. Idem, 1899, p. 305.

The figured specimen is quite typical of this species, which has, like the previous form, a very extensive geological range, viz., from the Rhaetic to recent.

Very rare at Gingin.

Marginulina inaequalis, *Reuss.*

(Plate VII., fig. 66.)

Marginulina inaequalis, Reuss, 1860, p. 59, pl. VII., fig. 3. Idem, 1862, p. 59, pl. V., fig. 13; pl. VI., fig. 8. Berthelin, 1880, p. 34. Chapman, 1894, p. 160, pl. IV., fig. 12. Egger, 1899. p. 94, pl. IX., fig. 4.

This species is an elongate modification of *M. glabra*, with a rather irregularly segmented test. It is peculiarly a Cretaceous form and has been recorded from the Gault and Chalk of Europe.

Very rare in the Gingin Chalk.

GENUS VAGINULINA, *d'Orbigny.*

Vaginulina legumen, *Linné sp.*

(Plate VIII., fig. 67.)

Nautilus legumen, Linné, 1767, p. 1164, No. 288.

Vaginulina legumen, L. sp., d'Orbigny, 1826, p. 257, No. 2. Jones, Parker, and Brady, 1866, p. 64, pl. IV., fig. 9. Brady, 1884, p. 530, pl. LXVI., figs. 13–15. Burrows, Sherborn and Bailey, 1890, p. 559, pl. X., fig. 16. Egger, 1899, p. 98, pl. IX., figs. 29, 30.

The examples in the present series are well developed tests, smooth, elongate, and subovate in section. They show no special characteristics as fossils of a particular horizon, and equally resemble some shells from the Lias as well as others from recent dredgings. Its range is from the Trias to recent.

Very abundant in the Gingin Chalk.

Vaginulina comitina, *Berthelin.*

(Plate VIII., fig. 68.)

Vaginulina comitina, Berthelin, 1880, p. 38, pl. I., figs. 21*a*-*d*. Chapman, 1894^2, p. 426, pl. VIII., fig. 11.

This fine species has been previously recorded from the Gault of France and England, from the Kentish Chalk or Chalk-marl, and the Cambridge Greensand.

Very rare at Gingin.

Vaginulina strigillata, *Reuss sp.*

(Plate VIII., fig. 69.)

Citharina strigillata, Reuss, 1845–6, pt. II., p. 106, pl. XXIV., fig. 29.

Vaginulina strigillata, Reuss, sp., Chapman, 1894², p. 423, pl. VIII., figs. 3*a*, *b* and 4. Egger, 1899, p. 101, pl. X., figs. 7, 9, and 12.

This rather variable form is essentially a Cretaceous species. It has occurred in the Gault and Chalk-marl of Folkestone, the Plänermergel (Cenomanian, etc.), of Bohemia, and the Chalk-marl of Bavaria.

Rare in the Gingin Chalk.

GENUS CRISTELLARIA, *Lamarck.*

Cristellaria planiuscula, *Reuss.*

(Plate VIII., fig. 70.)

Cristellaria planiuscula, Reuss, 1862, p. 71, pl. VII., figs. 15*a*, *b*, Berthelin, 1880, p. 53, pl. III., figs. 25*a*, *b*. Chapman, 1894³. p. 654, pl. X., figs. 14*a*, *b*. Egger, 1899, p. 114, pl. XII., figs. 7–9.

This species is one of the *C. crepidula* type, and is distinguished by its few chambers and rather short and broad test. Its distribution is limited to the Neocomian of Germany, the Gault of France and England, and the Chalk-marl of Bavaria.

Very rare at Gingin.

Cristellaria trunculata, *Berthelin.*

(Plate XII., fig. 121.)

Cristellaria trunculata (pars) Berthelin, 1880, p. 53, pl. III., figs. 27*a*, *b*. Chapman 1894³, p. 651, pl. X. figs, 4*a*, *b*. Id., 1899, p. 309. Egger, 1899, p. 111, pl. XII., figs. 18, 19.

C. trunculata is already known from the Gault of France and England, and from the Cambridge Greensand.

One specimen from Gingin.

Cristellaria tripleura, *Reuss.*

(Plate XII., fig. 120.)

Cristellaria tripleura, Reuss, 1860, p. 211, pl. IX., fig. 5. Id., 1862, p. 70. Chapman, 1894³, p. 652, pl. X., figs. 6*a*, *b*. Egger, 1899, p. 122, pl. XII., figs. 22–24.

This species is one of the smallest of the *Cristellariæ*. It has been found in the Gault of Folkestone and of Westphalia, and the Chalk-marl of Bavaria.

One specimen in the fine washings from Gingin.

Cristellaria lituola, *Reuss.*

(Plate VIII., fig. 71.)

Cristellaria lituola, Reuss, 1845–6, pt. II., p. 109, pl. XXIV., fig. 47. Chapman, 1894^3, p. 650, pl. IX., figs. 14*a*, *b*.

This form is only known from the Plänermergel of Bohemia and the Gault of Folkestone.

Very rare in the Gingin Chalk.

Cristellaria grata, *Reuss.*

(Plate VIII., fig. 72.)

Cristellaria grata, Reuss, 1862, p. 70, pl. VII., figs. 14*a*, *b*. Chapman, 1894^3, p. 713. Egger, 1899, p. 113, pl. XI., figs. 27, 28.

This is an ensiform variation of the *C. crepidula* type with rounded sides and gently curved back. It has been recorded from the Neocomian of Germany and England, and from the Chalk-marl of the Upper Bavarian Alps.

Very rare in the Gingin Chalk.

Cristellaria gladius, *Philippi sp.*

(Plate VIII., fig. 73.)

Marginulina gladius, Philippi, 1843, p. 40, pl. I., fig. 37.

Cristellaria gladius, Phil. sp., Chapman, 1894^3, p. 649, pl. IX., figs. 11*a*, *b*.

Although typically a Chalk form, this species has occurred in the Gault of Folkestone.

Very rare at Gingin.

Cristellaria acutauricularis, *Fichtel and Moll sp.*

(Plate VIII., fig. 74.)

Nautilus acutauricularis, Fichtel and Moll, 1798, p. 102, pl. XVIII., figs. *g-i*.

Cristellaria acutauricularis, F. and M. sp., Brady, 1884, p. 543, pl. CXIV., figs. 17*a*, *b*. Howchin, 1907, p. 42. Sherlock, 1914, p. 260, pl. XIX., fig. 2.

This species passes into *C. navicula* by the compression of the septal face of the last chamber.

C. acutauricularis, as noted by Mr. Howchin, ranges from the Lias to recent. Sherlock has lately recorded it from the Speeton Clay (Lower Cretaceous or Neocomian) of Yorkshire.

Previously recorded by Howchin from the Gingin Chalk as moderately common. Only one typical example found in my sample.

Cristellaria ovalis, *Reuss.*

(Plate VIII., fig. 75.)

Cristellaria ovalis, Reuss, 1845–6, pt. I., p. 34, pl. VIII., figs. 49*a*, *b* ; pl. XII., figs. 19*a*, *b* ; pl. XIII., figs. 60*a*-63*b*. Berthelin, 1880, p. 51. Howchin, 1907, p. 42.

This Gault and Cenomanian species has been recorded by Mr. Howchin from the Gingin Chalk. Several specimens occur in my sample.

Cristellaria schloenbachi, *Reuss.*

(Plate VIII., fig. 76.)

Cristellaria schloenbachi, Reuss, 1862, p. 65, pl. VI., figs. 14, Brady, 1884, p. 539, pl. LXVII., fig. 7. Chapman, 189 p. 649, pl. IX., figs. 9*a*, *b*. Egger, 1899, p. 110, pl. XII., fig 38–40; pl. XXIV., figs. 30, 31.

This species ranges from the Lower Cretaceous to recent. is perhaps more typical of Cretaceous deposits than of any oth

Moderately common at Gingin.

Cristellaria bronni, *Roemer sp.*

(Plate VIII., fig. 77.)

Planularia bronni, Roemer, 1841, p. 97, pl. XV., fig. 14.

Cristellaria bronni, Roemer, sp., Reuss, 1862, p. 70, pl. VII., fig 13*a*, *b*. Chapman, 1894³, p. 649, pl. IX., figs. 12*a*, *b*, 13*a*, *b*.

This is a Neocomian and Gault species in Europe.

At Gingin *C. bronni* is very rare.

Cristellaria italica, *Defrance sp.*

(Plate IX., fig. 78.)

Saracenaria italica, Defrance, 1824, vol. XXXII., p. 177; vo XLVII., p. 344. Atlas Conch., pl. XIII., fig. 6.

Cristellaria italica, Defr. sp., Brady, 1884, p. 544, pl. LXVIII figs. 17, 18, 20–23. Chapman, 1894³, p. 653, pl. X., fig 10*a*, *b*.

C. italica here passes into the shorter modification, *C. navicula* Typical specimens range from the Lower Cretaceous to recent. I is known from the Neocomian of Surrey, and from the Gault o England and France.

Rare at Gingin.

Cristellaria navicula, *d'Orbigny.*

(Plate IX., fig. 79.)

Cristellaria navicula, d'Orbigny, 1840, p. 27, pl. II., figs. 19, 20 Reuss, 1845–6, pt. I., p. 34, pl. XII., fig. 27. Chapman, 1894³ p. 650, pl. X., fig. 1. Egger, 1899, p. 116, pl. XII., figs. 3, 4.

This form is almost restrictedly a Cretaceous one, ranging from the Gault to the Upper Chalk.

Fairly common at Gingin.

Cristellaria triangularis, *d'Orbigny.*

(Plate IX., fig. 80.)

Cristellaria triangularis, d'Orbigny, 1840, p. 27, pl. II., figs. 21, 22. Reuss, 1845–6, pt. I., p. 34, pl. VIII., fig. 48. Chapman, 1894³, p. 651, pl. X., figs. 3*a*, *b*. Egger, 1899, p. 117, pl. XII., figs. 5, 6.

C. triangularis is typically Cretaceous and seems confined to the upper series of that formation.

Moderately common at Gingin.

Cristellaria latifrons, *Brady*.

(Plate XII., fig. 122.)

Cristellaria latifrons, Brady, 1884, p. 544, pl. LXVIII., fig. 19; pl. CXIII., fig. 11*a*, *b*. Chapman, 1894^{3}, p. 652, pl. X., figs. 8*a*, *b*.

The above species was represented by a single specimen in the English Gault, and it is here likewise unique. In recent soundings it occurs in fairly deep water.

Cristellaria oligostegia, *Reuss*.

(Plate IX., fig. 81.)

Cristellaria oligostegia, Reuss, 1860, p. 213, pl. VIII., fig. 8. Id., 1862, p. 93, pl. XIII., fig. 2. Marsson, 1878, p. 146. Berthelin, 1880, p. 56. Chapman, 1894^{3}, p. 651, pl. X., figs. 5*a*, *b*. Idem, 1894^{4}, p. 713. Id., 1899, p. 310. Egger, 1899, p. 118, pl. XI., figs. 21, 22.

This turgid and sparsely chambered form is well distributed through the Neocomian, Gault, and Chalk of Great Britain and the Continent.

A few specimens were found at Gingin.

Cristellaria gibba, *d'Orbigny*.

(Plate IX., fig. 82.)

Cristellaria gibba, d'Orbigny, 1826, vol. VII., p. 292, No. 17. Brady, 1884, p. 546, pl. LXIX., figs. 8, 9. Burrows, Sherborn, and Bailey, 1890, p. 559, pl. X., figs. 19*a*, *b*. Chapman, 1896, p. 4, pl. I., figs. 7*a*, *b*. Sherlock, 1914, p. 261, pl. XIX., figs. 9*a*, *b*.

Although this species has an extensive geological range, it is never so common as in the Cretaceous strata.

Abundant at Gingin.

Cristellaria articulata, *Reuss sp.*

(Plate IX., fig. 83.)

Robulina articulina, Reuss, 1864, p. 53, pl. V., figs. 62*a*, *b*; Pl. VI., figs. 63*a*, *b*.

Cristellaria articulata, Rss. sp., Brady, 1884, p. 547, pl. LXIX., figs. 10–12.

The earliest geological record of this species hitherto made was the Oligocene of Germany.

A single typical specimen was found in the Cretaceous at Gingin.

Cristellaria subalata, *Reuss.*

(Plate IX., fig. 84.)

Cristellaria subalata, Reuss, 1854, p. 68, pl. XXV., fig. 13. Chapman, 1896, p. 3, pl. I., figs. 3*a*, *b*. Egger, 1899, p. 118, pl. XI., figs. 19, 20.

This species, with raised sutures, is common throughout the Cretaceous, and is met with occasionally in Tertiary deposits.

It is frequent at Gingin.

Cristellaria gaultina, *Berthelin.*

(Plate IX., fig. 85.)

Cristellaria gaultina, Berthelin, 1880, p. 49, pl. III., figs. 15–19.

C. cultrata, Montf. sp., Burrows, Sherborn, and Bailey, 1890, p. 559, pl. X., figs. 18*a*, *b*. Chapman, 1896, p. 7, pl. I., figs. 10*a*, *b*, 11. Egger, 1899, p. 121, pl. XXIII., figs. 4–9. Sherlock, 1914, p. 262, pl. XVIII., figs. 27.

This is a compressed, numerously chambered form of the *C. rotulata* type. It is one of the most abundant of the *Cristellariæ* in the English Gault.

Very abundant at Gingin.

Cristellaria rotulata, *Lamarck sp.*

(Plate IX., fig. 86.)

Lenticulites rotulata, Lamarck, 1804, p. 188, No. 3 ; Tabl. Méthod, pl. CCCCLXVI., fig. 5.

Cristellaria rotulata, Lam. sp., d'Orbigny, 1840, p. 26, pl. II., figs. 15–18. Perner, 1892, p. 62, pl. IV., figs, 1–11. Chapman, 1896, p. 5, pl. I., figs. 8*a*, *b*. Perner, 1897, p. 47, 70, pl. VI., figs. 10, 11. Egger, 1899, p. 122, pl. XI., figs. 3, 4. Howchin, 1907, p. 42. Sherlock, 1914, p. 263, pl. XVIII., fig. 25.

Typical specimens of this well distributed species are not common in my sample from the Gingin Chalk. It was also met with in the same deposit by Mr. Howchin. Its range extends from the Lias to recent.

Cristellaria rotulata, *Lam. sp.*, var. microdiscus, *Reuss.*

(Plate IX., fig. 87.)

Cristellaria macrodisca, Reuss, 1862, p. 78, pl. IX., figs. 5*a*, *b*. Berthelin, 1880, p. 48, pl. III., figs. 6–11.

Cristellaria rotulata, Lam. sp., var. *macrodisca*, Reuss, Chapman, 1896, p. 6, pl. I., figs. 9*a*, *b*.

C. macrodisca, Rss., Egger, 1899, p. 120, pl. XI., figs. 5, 6.

This variety is familiar as a Cretaceous fossil, occurring in the Gault and Chalk-marl of England, France, and Germany.

Frequent at Gingin.

Cristellaria circumcidanea, *Berthelin.*

(Plate X., fig. 88.)

Cristellaria circumcidanea, Berthelin, 1880, p. 52, pl. III., figs. 1*a*, *b*. Chapman, 1896, p. 2, pl. I., figs. 2*a*, *b*. Idem, 1899, p. 310.

A keeled form with numerous, somewhat turgid chambers, and a small but prominent primordial chamber. It has been hitherto recorded only from the Gault of France and England; and from the Cambridge Greensand, a remanié bed of the Gault.

Several specimens of this distinct form were found at Gingin.

Cristellaria diademata, *Berthelin.*

(Plate X., fig. 89.)

Cristellaria diademata, Berthelin, 1880, p. 51, pl. III. figs. 4, 5, 12, 13. Chapman, 1896, p. 8, pl. II., figs. 2*a*, *b*. Perner, 1897, p 71, pl. VII., fig. 7. Egger, 1899, p. 120, pl. XI., figs. 1, 2. Chapman, 1899, p. 311.

A keeled form with undulate edge. The species has been recorded from the Gault of France and England, the Cambridge Greensand and the Chalk-marl of Bavaria. Perner also had it from the beds above the Cenomanian in Bohemia.

One specimen found at Gingin.

Cristellaria orbicularis, *d'Orbigny.*

Cristellaria orbicularis, d'Orbigny, Howchin, 1907, p. 42.

This species has been recorded from the Gingin Chalk by Mr. Howchin. No typical specimens were met with in my sample.

Cristellaria cultrata, *Montfort*, sp.

Cristellaria cultrata, Montfort sp., Howchin, 1907, p. 42.

Recorded by Mr. Howchin from Gingin.

GENUS FLABELLINA, *d'Orbigny.*

Flabellina rugosa, *d'Orbigny.*

(Plate X., fig. 90.)

Flabellina rugosa, d'Orbigny, 1840, p. 23, pl. II., figs. 4, 5, 7. Reuss, 1845–6, pt. I., p. 33, pl. VIII., figs. 31–34; pl. XIII., figs. 49, 53. Idem, 1860, p. 215. Marsson, 1878, p. 140. Chapman, 1892^{3}, p. 517. Perner, 1897, p. 72, pl. V., figs. 10, 16, 17, 19. Egger, 1899, p. 108, pl. X., figs. 5, 6; pl. XIII., figs. 1, 2.

F. rugosa is a well known Upper Cretaceous foraminifer, confined to the Chalk marl and Chalk, and possibly Upper Greensand (Cenomanian).

It is moderately common at Gingin.

Flabellina interpunctata, *von der Marck.*

(Plate X., fig. 91.)

Flabellina interpunctata, v. der Marck, 1858, p. 53, pl. I., fig. 5. Reuss, 1860, p. 216, pl. IX., fig. 1. Howchin, 1907, p. 42. Heron-Allen and Earland, 1910, p. 422, pl. VIII., fig. 5.

F. interpunctata is typically Upper Cretaceous.

SUB-FAM. POLYMORPHININÆ.

GENUS POLYMORPHINA, *d'Orbigny.*

Polymorphina sororia, *Reuss.*

(Plate X., fig. 92.)

Polymorphina (*Guttulina*) *sororia*, Reuss, 1862, p. 121, pl. II., figs. 25–29.

Polymorphina sororia, Rss., Brady, 1884, p. 562, pl. LXXI., figs. 15–16. Chapman, 1896, p. 12, pl. II., fig. 11. Egger, 1899, p. 126, pl. XVII., figs. 6, 7. Fornasini, 1900, p. 386, woodcut, fig. 36.

P. sororia is not confined to Cretaceous deposits, but is perhaps most abundant in beds of that age. Reuss' original specimens came from the Crag of Antwerp (Lower Pliocene), and it has also occurred in the Middle Oligocene of Germany and the Pliocene of East Anglia. The oldest records are those of Cretaceous age beginning with the Gault.

Frequent in the Gingin Chalk.

Polymorphina angusta, *Egger.*

(Plate X., fig. 93.)

Polymorphina (*Globulina*) *angusta*, Egger, 1857, p. 290, pl. XIII., figs. 13–15. Brady, 1884, p. 563, pl. LXII., figs. 1–3. Chapman, 1896, p. 13, pl. II., fig. 14. Egger, 1899, p. 126, pl. XVII., figs. 8, 9.

This species, as also the foregoing, ranges from the Upper Cretaceous to recent.

Rare at Gingin.

Polymorphina compressa, *d'Orbigny.*

(Plate X., fig. 94.)

Polymorphina compressa, d'Orbigny, 1846, p. 233, pl. XII., figs. 32–34. Brady, Parker, and Jones, 1870, p. 227, pl. XI., figs. 12*a-f*. Brady, 1884, p. 565, pl. LXXII., figs. 9–11.

P. communis, d'Orbigny, Burrows, Sherborn, and Bailey, 1890, p. 561, pl. XI., fig. 11.

P. compressa, d'Orb., Chapman, 1896, p. 14, pl. II., fig. 16.

This species has a wide geological range, beginning with the Lias.

It is rare at Gingin.

Polymorphina communis, *d'Orbigny.*

(Plate X., fig. 95.)

Polymorphina (*Guttulina*) *communis*, d'Orbigny, 1826, p. 266, pl. XII., figs. 1–4 ; Modèle, No. 62.
Guttulina cretacea, Alth., 1850, p. 262, pl. XIII., fig. 14.
Polymorphina cretacea, Alth. sp., Berthelin, 1880, p. 58.
Polymorphina communis, d'Orb., Brady, 1884, p. 568, pl. LXXII., fig. 19.
P. gibba, d'Orb., Burrows, Sherborn, and Bailey, 1890, p. 561, pl. XI., fig. 13. Chapman, 1896, p. 13, pl. II., fig. 15. Egger, 1899, p. 128, pl. XVII., figs. 36, 37.

The range of this species extends from the Lias to recent. In Cretaceous deposits it occurs in the Neocomian, Gault, and Red Chalk of England, and the Gault of France.

Rare at Gingin.

Polymorphina lactea, *Walker and Jacob sp.*

(Plate X., fig. 96.)

Serpula lactea, Walker and Jacob, 1798, p. 634, pl. XXIV., fig. 4.
Polymorphina lactea, W. and J. sp., Brady, 1884, p. 559, pl. LXXI., fig. II. Chapman, 1896, p. 9, pl. II., fig. 3. Egger, 1899, p. 127, pl. XVII., figs. 14, 15.

Occurs in many Cretaceous deposits in England and the continent. It dates from Jurassic times and its range extends to the recent.

Rare at Gingin.

GENUS SAGRAINA, *d'Orbigny* (*emend. Parker and Jones*).

Sagraina maitlandiana, *sp. nov.**

(Plate X., fig. 97.)

Description.—Test consisting of about six subpyriform to ovate segments arranged in a slightly curved line ; the first segment compound, consisting of a compact uvigerine series terminating in a blunt point at the aboral end. Apertural extremity extended as a tubular projection. Surface of test roughened with numerous blunt prickles.

Length of type specimen, 1·78mm. Diameter of last chamber, ·38mm.

Observations.—This species might easily be mistaken for *Nodosaria hispida*, d'Orbigny, but for the slight irregularity in size of the chambers as they increase in growth, whilst the complex primordial series shows it to belong to *Sagraina*. *Sagraina virgula*, Brady,† appears to be nearest to the above form, but differs essentially in the separation of the later component chambers by a stolon, by the everted mouth and by the hursute rather than asperulose test.

Not infrequent at Gingin.

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* Named after Mr. A. Gibb Maitland, Government Geologist of Western Australia, to whom the writer is indebted for the material.

† Rep. Chall, 1884, p. 583, pl. LXXVI., figs. 4–10.

Sagraina asperula, *Chapman.*

(Plate X., fig. 98.)

Sagraina asperula, Chapman, 1896[2], p. 581, pl. XII., fig. 1.

This is a stout form of *Sagraina* with few chambers, whic are closely conjoined, and with an obscure septation of the primordial series. Probably "*Dimorphina minuta*" of Dr. Egger* a slender variety of this form.

S. asperula was previously described from the lower zones the Gault of Folkestone.

Sagraina monile, *sp. nov.*

(Plate X., fig. 99.)

Description.—Test consisting of a linear series of about fo ovoid segments deeply constricted at the sutural lines, the commencing segment pyriform, formed of a complex uvigerine serie Aperture simple, orifice not greatly extended. Surface of te highly polished.

Length, ·62mm. Greatest width, ·15mm.

This species is represented by a single example in the Gingi Chalk.

SUB-FAM. RAMULININÆ.

GENUS RAMULINA, *Rupert Jones.*

Ramulina aculeata, *Wright.*

(Plate X., fig. 100.)

Ramulina aculeata, Wright, 1886, p. 331, pl. XXVII., fig. 11.

Lagena hispida, Haeusler, 1887, pp. 185 and 189, pl. V., fig. 1

Ramulina aculeata, Burrows, Sherborn, and Bailey, 1890, p. 561 pl. XI., fig. 16.

Lagena tuberculata, Perner, 1892, p. 56, pl. V., figs 19*a*, *b*.

Ramulina globulifera, var. *miocaenica*, Rzehak, 1895, p. 222, p VI., fig. 6.

R. kittli, Idem, ibid, p. 222, pl. VI., figs. 8, 10.

R. aculeata, Wright, Chapman, 1896[2], p. 583, pl. XII., figs. 7– Jones and Chapman, 1897, p. 345, figs. 23–42. Chapman 1899, p. 314. Egger, 1899, p. 135, pl. II., fig. 3.

This is a typically Upper Cretaceous species, having bee found only rarely in later deposits, as the Miocene. It is distinguished from the more typically recent species, *R. globulifera*, b the strong prickly or tuberculate ornament of the test.

Fragmentary specimens occur at Gingin.

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* Foram. und Ostrakoden aus dem Kreidemergeln der Oberbayerischen Alpen, 1899, p. 124, pl. XXII. fig. 22.

Genus Vitriwebbina, *Chapman.*

Vitriwebbina laevis, *Sollas sp.*

(Plate XI., fig. 101).

Webbina laevis, Sollas, 1877, pp. 103, 104, pl. VI., figs. 1–3.

Vitriwebbina laevis, Sollas sp., Chapman, 1892^4, p. 53, pl. II., fig. 4 Bagg, 1895, p. 12. Chapman, 1896^2, p. 585, pl. XII., fig, 12. Idem, 1896^3, p. 332, fig. 3. Bagg, 1898, p. 36, pl. II., figs. 4*a*, *b*.

V. sollasi occurs in the Gault and Chalk marl of England and in the Middle Marl of New Jersey (Upper Cretaceous).

Several good examples of this interesting species, attached to shell fragments, occur at Gingin.

Fam. GLOBIGERINIDÆ.

Genus Globigerina, *d'Orbigny.*

Globigerina bulloides, *d'Orbigny.*

(Plate XII., fig. 123.)

Globigerina bulloides, d'Orbigny, 1826, vol. VII., p. 277, No. 1. Modèles Nos. 17 and 76. Brady, 1884, pp. 593–5, pl. LXXVII., LXXIX., figs. 3–7. Chapman, 1896^2, p. 587, pl. XIII., fig. Howchin, 1907, p. 42.

This species has been recorded by Mr. Howchin as very common in the Gingin Chalk. A few specimens were also found in the sample received by the writer.

Globigerina cretacea, *d'Orbigny.*

(Plate XI., fig. 102 ; pl. XII., fig. 124.)

Globigerina cretacea, d'Orbigny, 1840, p. 34, pl. III., figs. 12–14. Reuss, 1845–6, pt. I., p. 36, pl. VIII., figs. 55*a*, *b*. Burrows, Sherborn, and Bailey, 1890, p. 561, pl. XI., figs. 18*a*-*c*. Perner, 1892, p. 64, pl. IX., figs. 7–10. Chapman, 1892^2, p. 517, pl. XV., figs. 13*a*-*c*. Id., 1896^2, p. 588, pl. XIII., figs. 5, 6. Egger, 1899, p. 169, pl. XXI., figs. 1–3, 10.

The tests in these washings are somewhat undersized. They are of the typical Cretaceous form, and unlike the more recent modification which has a higher and stouter test.

Not rare.

Globigerina aequilateralis, *Brady.*

(Plate XII., fig. 125.)

Globigerina aequilateralis, Brady, 1884, p. 605, pl. LXXX., figs 18–21. Wright, 1886, p. 332, pl. XXVII., figs. 9*a*, *b*. Chapman, 1892^{3}, p. 517, pl. XV., figs. 14*a*, *b*. Id., 1896^{2}, p. 589 pl. XIII., fig. 7. Egger, 1899, p. 169, pl. XXI., figs. 9, 11 21–23. Idem, 1907, p. 48, pl. VI., figs, 24, 25. Id., 1910 p. 36, pl. IV., figs. 17–19. Cushman, 1914, p. 12, pl. II., figs 1–3 ; pl. X., fig. 5.

The Cretaceous specimens as a rule are depressed and mor closely coiled than the recent examples. Those occurring in th present series are very minute.

Very common in the fine washings of the Gingin Chalk.

Globigerina marginata, *Reuss.*

(Plate XII., fig. 126.)

Rosalina marginata, Reuss, 1845–6, pt. I., p. 36., pl. VIII., figs 54, 74 ; pl. XIII., fig. 68. Egger, 1899, p. 171, pl. XXI., figs 12–14.

This and the following species are closely related and have ofte been confused. Thus Dr. Brady figures a fossil specimen in the "Challenger" Report (pl. LXXXII., fig. 12*a*, *b*) as *G. linnaeana* but which by its inflated chambers agrees with Reuss' species fro the Bohemian Chalk. Both species are superficially rugose an with peripheral limbation, but in *G. linnaeana* the chambers are no inflated. *G. marginata* is a well known Cretaceous species i Europe and England.

Very common at Gingin.

Globigerina linnaeana, *d'Orbigny sp.*

(Plate XI., fig. 103.)

Rosalina linnaeana, d'Orbigny, 1839, p. 101, pl. V., figs. 10–12.

R. canaliculata, Reuss, 1854, p. 70, pl. XXVI., figs. 4*a*, *b*.

Globigerina linnaeana, Brady, 1884, p. 598, pl. CXIV., figs. 21*a*-*c* (copied from d'Orbigny).

Globigerina canaliculata, Reuss sp., Egger, 1899, p. 172, pl. XXI., figs. 15–17, 24–26.

This form is distinguished by its concave chambers, being isomorphous with *Discorbina concava* and *Truncatulina ariminensis*, as pointed out by Dr. H. B. Brady (Rep. Chall., p. 599).

G. linnaeana occurs in several European Cretaceous faunas as well as in the Crag of East Anglia, and in recent soundings. Mr. Howchin recorded it as very common at Gingin.

Frequent in my sample.

GENUS SPHAEROIDINA, *d'Orbigny.*

Sphaeroidina bulloides, *d'Orbigny.*

(Plate XII., fig. 127.)

Sphaeroidina bulloides, d'Orbigny, 1826, vol. VII., p. 267, No. 1—Modèle, No. 65. Brady, 1884, p. 620, pl. LXXXIV., figs. 1–7. Burrows, Sherborn, and Bailey, 1890, p. 562, pl. XI., figs. 20, 21. Chapman, 1896², p. 589, pl. XIII., fig. 8. Egger, 1899, p. 173, pl. XXI., figs. 29. 30.

This well distributed form ranges from the Cretaceous to recent.

A single specimen found at Gingin.

FAM. ROTALIIDÆ.

SUB-FAM. ROTALIINÆ.

GENUS DISCORBINA, *Parker and Jones.*

Discorbina opercularis, *d'Orbigny sp.*

Discorbina opercularis, d'Orbigny sp., Howchin, 1907, p. 43.

This species was recorded by Howchin from the Gingin Chalk, and he remarks that "The examples are small and delicate, but perfectly characteristic. Rather scarce." Not found in my sample.

GENUS TRUNCATULINA, *d'Orbigny.*

Truncatulina lobatula, *Walker and Jacob sp.*

(Plate XI., figs. 14*a*, *b*.)

Nautilus lobatulus, Walker and Jacob, 1784, p. 20, pl. III., fig. 71.

Truncatulina lobatula, W. and J. sp., Brady, 1884, p. 660, pl. XCII., fig. 10; pl. XCIII., figs. 1, 4, 5: pl. CXV., figs. 4, 5. Chapman, 1898, p. 2, pl. I., figs. 2*a*, *b*. Egger, 1899, p. 151, pl. XXIII., figs. 12–14. Howchin, 1907, p. 43.

This usually common and well distributed form is rare at Gingin.

Truncatulina convexa, *Reuss.*

(Plate XI., figs. 105*a*, *b*.)

Truncatulina convexa, Reuss, 1851, p. 36, pl. III., fig. 4. Uhlig, 1886, p. 180, pl. III., fig. 1. Egger, 1899, p. 149, pl. XVIII., figs. 25–27.

T. convexa appears to take the place of *T. lobatula* at Gingin. It is separated from the latter species by its concave superior face and highly convex inferior with inflated chambers. It is a characteristic Cretaceous species occurring in the Chalk of Europe and the Greensand of New Jersey.

Very common in the present sample.

Truncatulina variabilis, *d'Orbigny.*

Truncatulina variabilis, d'Orbigny, Howchin, 1907, p. 43.

Recorded by Howchin from Gingin.

Truncatulina wuellerstorfi, *Schwager sp.*

(Plate XI., fig. 106.)

Anomalina wuellerstorfi, Schwager, 1866, p. 258, pl. VII., figs. 105, 107.

Truncatulina wuellerstorfi, Schwager sp., Brady, 1884, p. 662, pl. XCIII., figs. 8, 9. Uhlig, 1886, p. 174, fig. 3. Chapman, 1898, p. 3, pl. I., figs. 3*a-c*.

This species ranges through the Lower Greensand and Gault of England, the Cenomanian or Middle Marl beds of New Jersey, the London Clay of London, and the Lower Pliocene of Kar Nicobar. It is generally common in recent soundings in high latitudes.

Rare at Gingin.

GENUS ANOMALINA, *d'Orbigny.*

Anomalina ammonoides, *Reuss sp.*

(Plate XI., fig. 107.)

Rosalina ammonoides, Reuss, 1845-6, pt. I., p. 36, pl. XVIII., fig. 53 ; pl. XIII., fig. 66.

Anomalina ammonoides, Rss. sp., Brady, 1884, p. 672, pl. XCIV., figs. 2, 3. Chapman, 1898, p. 4, pl. I., figs. 5*a-c*. Egger 1899, p. 152, pl. XVIII., figs. 10-12.

This species is rare at Gingin.

GENUS PULVINULINA, *Parker and Jones.*

Pulvinulina elegans, *d'Orbigny, sp.*

(Plate XI., fig. 108.)

Rotalia (Turbulina) elegans, d'Orbigny, 1826, p. 276, No. 54.

Pulvinulina elegans, d'Orb. sp., Parker, Jones, and Brady, 1871, p. 174, pl. XII., fig. 142. Sherborn and Chapman, 1889, p. 487, pl. XI., figs. 30-32. Chapman, 1898, p. 6, pl. I., figs. 8*a-c*.

This species is here represented by the shallow-water variety with depressed test. Rather rare.

Pulvinulina cordieriana, *d'Orbigny sp.*

(Plate XI., figs. 109*a*, *b*.)

Rotalina cordieriana, d'Orbigny, 1840, p. 33, pl. III., figs. 9-11. Egger, 1899, p. 158, pl. XX., figs. 16-18.

Formerly recorded from the White Chalk of the Paris Basin and from the Chalk marl of the Upper Bavarian Alps.

Rare at Gingin.

Pulvinulina spinulifera, *Reuss sp.*
(Plate XI., fig. 110).

Rotalia spinulifera, Reuss, 1862, p. 93, pl. XIII., figs. 3*a*, *b*, 4*a-c*, 5*a-c*.

Epistomina spinulifera, Reuss sp., Uhlig, 1883, p. 768, pl. VII., figs. 5–7.

Pulvinulina spinulifera, Reuss sp., Chapman, 1898, p. 9, pl. II., figs. 1*a-c*.

Rotalina spinulifera, Rss. sp., Egger, 1899, p. 162, pl. XXI., figs. 42–44.

With the exception of its solitary occurrence in the Oxfordian (Upper Jurassic) of Russia, this species appears to be hitherto known only from the Gault and Chalk marl. The West Australian specimens are small and poorly developed compared with specimens from the English Gault.

Rare at Gingin.

GENUS ROTALIA, *Lamarck*.

Rotalia soldanii, *d'Orbigny*, var. nitida, *Reuss*.
(pl. XI., fig. 111.)

Rotalina nitida, Reuss, 1844, p. 214. Idem, 1845-6, pt. I., p. 35, pl. VIII., fig. 52; pl. XII., figs. 8, 20.

Placentula nitida, Rss. sp., Berthelin, 1880, p. 69, pl. IV., figs. 11*a-c*.

Discorbina oligostegia, Perner, 1892, p. 65, pl. X., figs. 5*a*, *b*.

Rotalia umbilicatula, var. *nitida*, Rss., Perner, 1897, pp. 54, 55, and 72, pl. VII., fig. 25, woodcut, p. 53.

Rotalia soldanii, d'Orb. var *nitida*, Rss., Chapman, 1898, p. 9, pl. II., figs. 2*a-c*.

Rotalina nitida, Rss., Egger, 1899, p. 156, pl. XX., figs. 4–6. Id., 1907, p. 46, pl. VI., figs. 13–15.

This variety is smaller and neater than the specific form. It ranges through the Albian, Cenomanian, and Turonian of Europe (Gault to Chalk marl).

Rather rare at Gingin.

Rotalia beccarii, *Linné.*

Rotalia beccarii, Linné, Howchin, 1907, p. 43.

This species has been recorded by Mr. Howchin as rare at Gingin.

Rotalia broeckiana, *Karrer.*

Rotalia brœckiana, Karrer, Howchin, 1907, p. 43.

Recorded by Howchin as rather scarce at Gingin.

FAM. NUMMULINIDÆ.

SUB-FAM. POLYSTOMELLINÆ.

GENUS NONIONINA, *d'Orbigny*.

Nonionina asterizans, *Fichtel and Moll sp.*

Nonionina asterizans, Fichtel and Moll sp., Howchin, 1907, p. 43.

A single example was recorded from Gingin by Mr. Howchin.

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GENERAL REMARKS ON THE OSTRACODAL FAUNA OF GINGIN.

The following species and varieties are here recorded :—

- *Paracypris siliqua*, Jones and Hinde.
- *Bairdia arquata*, Münster sp.
- *Macrocypris simplex*, Chapman, var. *africana*, var. nov.
- *Bythocypris howchiniana*, sp. nov.
- *Cythere harrisiana*, Jones, var. *reticosa*, Jones and Hinde.
  - „ *westraliensis*, sp. nov.
  - „ *lineatopunctata*, Chapman and Sherborn.
- *Cythereis ornatissima*, Reuss. sp.
  - , „ var. *nuda*, Jones and Hinde.
  - „ „ var. *reticulata*, J. and H.
  - „ „ var. *stricta*, J. and H.
  - „ *quadrilatera*, Römer sp.
  - „ *rudispinata*, Chapman and Sherborn.
  - „ *tuberosa*, J. and H.
- *Cytheropteron concentricum*, Reuss sp.
- *Cytherella muensteri*, Römer sp.
  - „ *ovata*, Römer sp.
  - „ *williamsoniana*, Jones.
  - „ „ var. *stricta*, J. and H.
  - „ *chapmani*, J. and H.

Amongst the already described forms, nine are restricted to Gault and Chalk, viz.:—*Paracypris siliqua*, *Cythereis ornatissima*, and vars. *nuda*, *reticulata*, and *stricta*, *Cytheropteron concentricum*, *Cytherella muensteri*, *C. ovata*, and *C. williamsoniana*. Five are peculiarly Gault forms, viz.:—*Cythere harrisiana* var. *reticosa*, *C. lineatopunctata*, *Cythereis rudispinata*, *Cytherella williamsoniana* var. *stricta* and *C. chapmani*. One species only is restricted to the Chalk formation, viz.:—*Cythereis tuberosa*, whilst *Bairdia arquata* is a Chalk and Tertiary form. One species, *Cythereis quadrilatera*, ranges from the Neocomian to the Upper Cretaceous.

The balance of evidence from the Ostracoda is therefore clearly in favour of a correlation with the lower part of the Upper Cretaceous, that is, Albian. Another point worth especial notice is the similarity of at least two West Australian Jurassic species to our present *Cythere westraliensis*. The South African Cretaceous in the neighbourhood of the Buffalo River shows a striking faunal resemblance to that of the Australian.

THE OSTRACODA.

FAM. CYPRIDIDÆ.

GENUS PARACYPRIS, *G. O. Sars*.

Paracypris siliqua, *Jones* and *Hinde*.

(Plate XIII., fig. 1.)

Paracypris siliqua, Jones and Hinde, 1890, p. 2, pl. II., figs. 48, 49, 51 ; pl. III., figs. 33, 34. Chapman, 1893, p. 346. Idem, 1898, p. 332. Egger, 1899, p. 179, pl. XXVII., figs. 16, 17.

In Britain this species is found in the Gault of Folkestone, the Cambridge Greensand (derived from the Gault), and is well distributed in the Chalk. In the latter formation it has been recorded from counties Antrim and Londonderry, Ireland ; and from Horstead, Norfolk, England. Egger found this species in the Chalk-marl of the Bavarian Alps.

P. siliqua is represented in the present collection by several valves which agree very closely with those found in the northern hemisphere.

FAM. BAIRDIDÆ.

GENUS BAIRDIA, *McCoy*.

Bairdia arquata, *Munster sp.*

(Plate XIII., fig. 3.)

Cythere arquata, Münster, 1830, p. 63.

Bairdia arcuata, Egger, 1899, p. 178, pl. XXVII., figs. 1–3.

Von Münster named this species *arquata* from its locality, Castell' arquato, and the original spelling should therefore be adhered to.

This neat and slender *Bairdia* has not been recorded from the European Cretaceous excepting the Chalk-marl of Bavaria. It is a well known form in the Oligocene and Miocene of Germany. It is very rare at Gingin.

GENUS MACROCYPRIS, *Brady*.

Macrocypris simplex, var. africana, var. nov.

(Plate XIII., fig. 4.)

Macrocypris simplex, Chapman (pars), Chapman, 1904, p. 233, pl. XXIX., figs. 22, 22*a*, *b*.

This variety of the species originally described from the Cambridge Greensand was figured as an aberrant form of *M. simplex* ; it was found amongst the Pondoland Cretaceous Ostracoda. It is distinct from *M. simplex* in the more strongly arched dorsum and the flexuous ventral border ; whilst the anterior of the carapace is not so acuminate.

The occurrence of this variety in the present series is extremely interesting, since the age of the Pondoland Cretaceous as determined by its microzoa appears to be that of the lower part of the Upper Cretaceous.

One specimen from Gingin.

GENUS BYTHOCYPRIS, *Brady*.

Bythocypris howchiniana, sp. nov.*

(Plate XIII., figs. 2*a*-*c*.)

Description.—Carapace seen from the side, suboval, the anterior narrower than the posterior and evenly rounded ; back strongly arched in the median line and obliquely rounded towards the hinder end where it meets the almost straight ventral border at an obtuse angle. Edge view of carapace long-elliptical with sharp extremities ; left valve larger than right. End view sub-cordate and tumid.

Length, ·8mm. ; height, ·4mm. ; thickness of carapace, ·28mm.

This species comes nearest to *Bythocypris brownei*, Jones and Hinde,† in general form, but that the latter has a more evenly rounded carapace at both ends.

Two examples were found at Gingin.

FAM. CYTHERIDÆ.

GENUS CYTHERE, *Muller*.

Cythere harrisiana, *Jones*, var. reticosa, *Jones and Hinde*.

(Plate XIII., fig. 6.)

Cythere harrisiana, var. *reticosa*, Jones and Hinde, 1890, p. 18., pl. I., fig. 46.

This variety is usually smaller than the specific form, and is one of the smallest ostracod valves in the present collection.

C. harrisiana, var. *reticosa* is a restricted Gault fossil, and has only been recorded from two localities, in Kent and Surrey, England.

One specimen from the Gingin Chalk.

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* Named after Mr. Walter Howchin, F.G.S., who previously investigated this fossil deposit.

† A Supplementary Monograph of the Cretaceous Entomostraca of England and Ireland. Pal. Soc. Mon. for 1889, p. 13. pl. III., Figs. 38, 39, 42, 43.

Cythere westraliensis, *sp. nov.*

(Plate XIII., figs. 7*a*, *b*, 8.)

Description.—Carapace seen from the side, elongate-ovate to pyriform. The specimens appear to fall into two series, that variety which is elongate having a subangulate dorsal margin, whilst the pyriform valves have a rounded back. The ventral border is slightly convex. The antero- and postero-ventral angles are sharp. Anterior border obliquely rounded towards the back ; posterior more gently rounded and narrower than the anterior. Both extremities are margined with a conspicuous flange. Edge view, long-ovate, more compressed at the anterior end. End view broadly ovate. Surface ornamented with conspicuous pittings arranged in a quasi-concentric manner. The post-ventral angle generally bears a blunt spine.

Length of larger specimen, 1·08mm. ; height, ·73mm. ; thickness of carapace, ·5mm.

The subpyriform shape and concentric foveolate ornament of this species seems to point to an ancestral relationship with the living *Cythere demissa*, or a species of that type, several of which are now found living in the Southern Ocean. It is possible that the longer and more posteriorly tumid form represents the female of the species. At first sight one might be inclined to refer this species to the genus *Cytheridea*. The hinge-line, however, is in agreement with *Cythere*, and further, the carapace is more compressed than in typical Cytherideas. Closely related to this species is Rupert Jones' *Cythere drupacea*,[*] with an ovate and swollen carapace, recorded in strata from the Richmond Well boring at 1,205 feet, and probably on the Great Oolite horizon. *C. drupacea*, however, has a more pointed posterior end and a steeper ventral face, whilst the postero-ventral spine is absent. It is interesting to note that *C. drupacea* is recorded with some reservation from the Upper Cretaceous of East Pondoland, South Africa.[†] A variety of *Cythere drupacea* (var. *fortior*) was described by the writer from the Jurassic of the Greenough River District, W. Australia [‡] ; this form differs from *C. westraliensis* in the particulars enumerated for the English specimens of *C. drupacea*. Our figure 7 suggests a further relationship with *C. corrosa*, Jones and Sherborn, var. *grossepunctata*, Chapman, from the Jurassic of W. Australia,[§] which is, however, a more tumid form, and having rounder extremities.

Common at Gingin.

Cythere lineatopunctata, *Chapman and Sherborn.*

(Plate XIV., fig. 9.)

Cythere lineatopunctata, Chapman and Sherborn, 1893, pp. 346, 348, pl. XIV. fig. 4 (marked 2 in error on plate).

A neat example of this English Gault species has occurred in the present sample. The anterior of the valve is not quite so widely expanded as in the Gault specimens, but in all other points it closely agrees with the species.

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[*] Quart. Journ. Geol. Soc., Vol. XL. 1884, p. 772, pl. XXXIV., fig. 30.

[†] Chapman. Annals. S. African Museum, Vol. IV., part V. 1904, p. 234.

[‡] Proc. R. Soc. Vict Vol. XVI. (N.S.) pt. II. 1904, p. 199, pl. XXIII., figs 3, 3*a*, *b*.

[§] Ibid., p. 200, pl. XXIII., figs. 5, 5*a*, *b*.

One specimen in the fine washings from Gingin.

GENUS CYTHEREIS, *Jones.*

Cythereis ornatissima, *Reuss sp.*

(Plate XIV., fig. 10.)

Cytherina ornatissima, Reuss, 1845–6, p. 104, pl. XXIV., figs. 12 and 18.

Cythereis ciliata, Jones, 1849, p. 19, pl. IV., figs. 11*a-h.*

Cypridina muricata, Reuss, 1851, p. 50, pl. V., figs. 12*a-c.*

Cythere ornatissima, Reuss, 1874, p. 146, pl. XXVII., figs. 5, 6*a-c.*

Cythere (Cythereis) ornatissima, Jones, 1875, pp. 79 and 81.

Cythereis ornatissima, Reuss sp., Jones and Hinde, 1890, p. 21, pl. II., figs. 1–7, 15, 16 ; pl. IV., figs. 7, 8. Egger, 1899, p. 182, pl. XXVII., fig. 35.

This is one of the commonest Upper Cretaceous ostracods. It was most abundant in zone X of the Gault at Folkestone. It also occurs in the Chalk-marl and Chalk of many localities both in England and on the continent (Bohemia, Bavaria, etc.).

Very common at Gingin.

Cythereis ornatissima, *Reuss sp.*, var. nuda, *Jones and Hinde.*

(Plate XIII., fig. 5 ; Plate XIV., fig. 11.)

Cythereis cornuta (non Roemer), Jones, 1849, p. 21 pl. V., figs. 13*ae.*-

Cythereis ornatissima, Rss. sp., Jones and Hinde, 1890, p. 23, pl. I., fig. 76 ; pl. II., figs. 9, 12–14 ; pl. IV., fig. 14.

This nearly smooth variety is met with in abundance in the Gault of Folkestone. It has also occurred in the Chalk-marl and Chalk of England.

Very common at Gingin.

Cythereis ornatissima, *Reuss sp.*, var. reticulata, *Jones and Hinde.*

(Plate XIV., fig. 12.)

Cythereis ornatissima, Reuss sp., var. *reticulata,* Jones and Hinde, 1890, p. 24, pl. I., figs. 67, 68, 77 ; pl. IV., figs. 9–12.

The neatly reticulated surface and conspicuous sub-central boss distinguish this variety. It has been noted from the Gault of Folkestone, the Chalk-marl and Chalk of England, and the Chalk of Antrim, Ireland.

It is abundant at Gingin.

Cythereis ornatissima, *Reuss sp.*, var. stricta, *Jones and Hinde.*

(Plate XIV., fig. 13.)

Cythereis ornatissima, Rss. sp., var. *stricta,* Jones and Hinde, 1890, p. 25, pl. I., fig. 63.

This is a small variety with accentuated dorsal and ventral ridges and a finely reticulated surface.

It was found in the Folkestone Gault and the Chalk-marl of Didcot, England.

Rare at Gingin.

Cythereis quadrilatera, *Roemer sp.*

(Plate XIV., fig. 14.)

Cytherina quadrilatera, Roemer, 1840, p. 105, pl. XVI., fig. 19.

Cythereis quadrilatera, Roemer sp., Jones, 1849, p. 18, pl. III., fig 10*a-f*; pl. IV., 10*g-j*.

Cythere (*Cythereis*) *quadrilatera*, Jones, 1884, pp. 766, 772, pl. XXXIV., figs. 39–41.

Cythereis quadrilatera, Roemer sp., Jones and Hinde, 1890, p. 2 pl. I., figs. 69–75.

The present is a young example of the species defined as suc by the unbroken median ridge. Its history dates from the Ne ocomian (of the Richmond boring), occurring through the Gault an Chalk of England and the Chalk of North Germany, Saxony, an Bohemia. A similar form is noted from the Portlandian of Dorse by Rupert Jones.

One specimen from Gingin.

Cythereis rudispinata, *Chapman and Sherborn.*

(Plate XIV., fig. 15.)

Cythereis rudispinata, Chapman and Sherborn, 1893, pp. 347, 348 pl. XIV., fig. 67.

This species is characterised by having three parallel rows o boss-like spines on the valves. It was found well distributed in the Gault of Folkestone and has not since occurred in any other formation.

Not uncommon in the Gingin rock.

Cythereis tuberosa, *Jones and Hinde.*

(Plate XIV., fig. 16.)

Cythereis tuberosa, Jones and Hinde, 1890, p. 26, pl. III., figs. 2, 3.

This species originally came from the Upper Chalk of Horstead, Norfolk, and has not been recorded elsewhere.

One example from Gingin.

GENUS CYTHEROPTERON, *Sars.*

Cytheropteron concentricum, *Reuss sp.*

(Plate XIV., fig. 17.)

Cytherina concentrica, Reuss, 1846, pp. 104, 105, pl. XXIV., figs. 22*a-c*.

Cythere concentrica, Rss. sp., Kafka, 1887, p. 14, fig. 27.

Cytheropteron concentricum, Reuss sp., Jones and Hinde, 1890, p. 31, pl. I., figs. 5–10; pl. IV., fig. 19. Chapman and Sherborn, 1893, Table, p. 347. Egger, 1899, p. 185, pl. XXVII., fig. 51.

This species is confined to the Upper Cretaceous formations (Albian to Senonian). It was excessively common in zone X of the Folkestone Gault. The West Australian specimens are typical, and show, by the absence of prickles between the pittings, that they are old or worn examples.

Common at Gingin.

FAM. CYTHERELLIDÆ.

GENUS CYTHERELLA, *Jones.*

Cytherella muensteri, *Roemer sp.*

(Plate XIV., fig. 18.)

Cytherina muensteri, Roemer, 1838, p. 516, pl. VI., fig. 13.

Cytherella muensteri, Roemer sp., Jones and Hinde, 1890, p. 46, pl. III., figs. 63–67. Egger, 1899, p. 187, pl. XXVII., figs. 48–50.

The Australian examples are in every way comparable with the Albian to Senonian fossils of Europe.

Abundant at Gingin.

Cytherella ovata, *Roemer sp.*

(Plate XIV., fig. 19.)

Cytherina ovata, Roemer 1840, p. 104, pl. XVI., fig. 21.

Cytherella ovata, Roemer, sp., Jones 1849, p. 28, pl. VII., figs. 24*a*-*i*. Jones and Hinde, 1890, p. 44, pl. III., figs. 48–54 ; pl. IV., fig. 39. Egger, 1899, p. 186, pl. XXVII., figs. 54–56.

This is a widely distributed Cretaceous species, being found in the Gault, Upper Greensand and Chalk of England and Ireland. It is also a well known fossil in the European Cretaceous, and has been doubtfully recorded from the Neocomian of France. Some of the present specimens closely approach *C. obovata*, Jones and Hinde, from the Chalk of Kent, in having unequally rounded ends.

Frequent at Gingin.

Cytherella williamsoniana, *Jones.*

(Plate XIV., fig. 20.)

Cytherella williamsoniana, Jones, 1849, p. 31, pl. VII., figs. 26*a*-*h*. Bosquet, 1854, p. 62, pl. V., figs. 2*a*-*d*. Reuss, 1874, p. 153, pl. XXVIII., figs. 9, 10*a*, *b*. Marsson, 1880, p. 31, pl. II., figs. 8*a*-*c*. Egger, 1899, p. 188, pl. XXVII., figs. 63–65.

The Australian specimens have the median lateral ornament of a curved ridge very pronounced. Previously recorded from the Gault of Kent and Surrey, the Upper Greensand of Ventnor (I. of Wight), and the Chalk of the South-east of England, Norfolk and Ireland. In Europe it occurs in the Chalk of Saxony and the I. of Rügen.

Common at Gingin.

Cytherella williamsoniana, *Jones*, var. stricta, *Jones* and *Hinde.* (Plate XIV., fig. 21.)

Cytherella williamsoniana, var. *stricta*, Jones and Hinde, 1890, p. 48, pl. III., fig. 71.

Elsewhere this variety is confined to the Gault of Kent and Surrey.

Rare at Gingin.

Cytherella chapmani, *Jones* and *Hinde.*

(Plate XIV., fig. 22.)

Cytherella chapmani, Jones and Hinde, 1890, p. 49, pl. III., fig. 70.

In this species the median ridges form a compressed spiral. Hitherto known only from the Gault of Folkestone and Godstone, England.

One specimen at Gingin.

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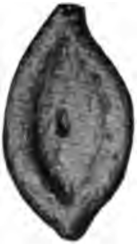
Plate I.

1



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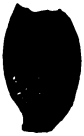

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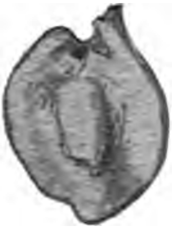

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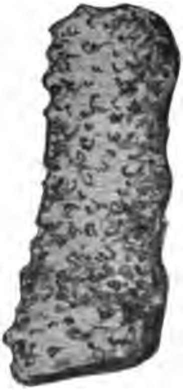

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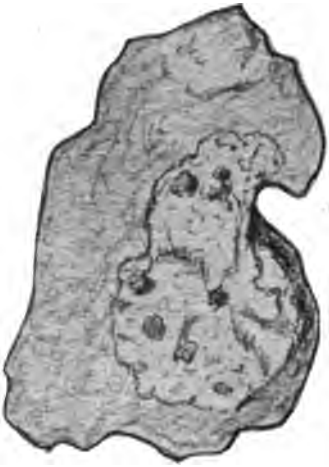

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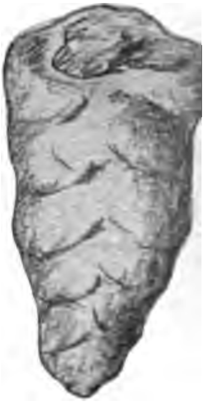

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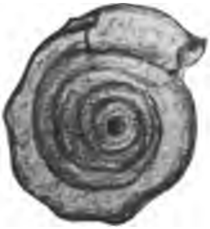

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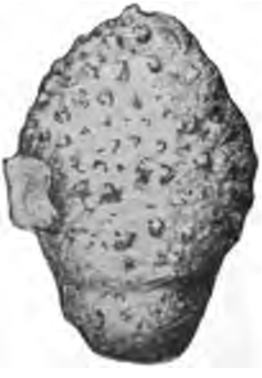

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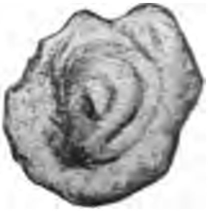

EXPLANATION OF PLATE I.

Fig. 1.—*Spiroloculina asperula*, Karrer sp., ×37.
„ 2.—*Miliolina venusta*, Karrer sp., ×37.
„ 3.—*Massilina ginginensis*, sp. nov., ×37.
„ 4.—*Rhizammina indivisa*, Brady, ×37.
„ 5.—*Placopsilina cenomana*, d'Orb., ×37.
„ 6.—*Haplostiche soldanii*, Jones and Parker sp., ×18.
„ 7.—*Ammodiscus incertus*, d'Orb. sp., ×37.
„ 8.— „ *gaultinus*, Berthelin, ×37.
„ 9.—*Textularia turris*, d'Orb., ×37.

Plate II.

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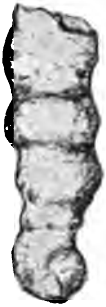

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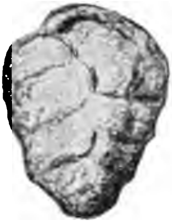

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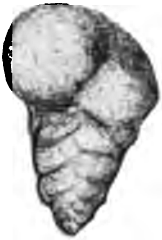

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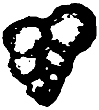

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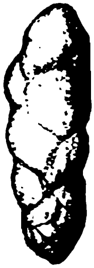

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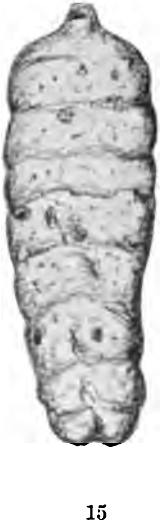

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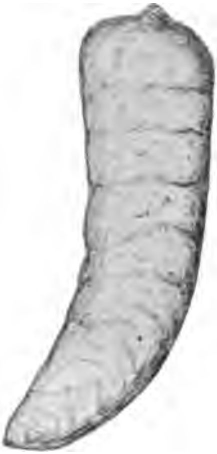

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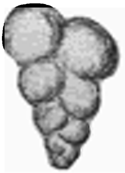

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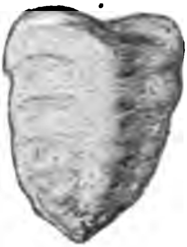

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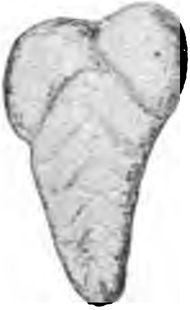

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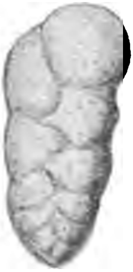

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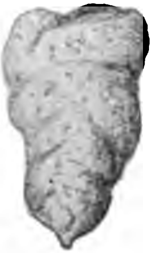

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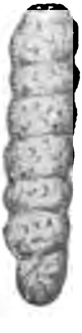
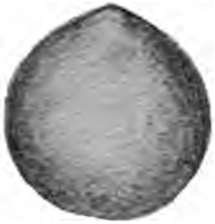


EXPLANATION OF PLATE II.

Fig. 10.—*Haplophragmium agglutinans*, d'Orb. sp., ×37.
" 11.—*Textularia gibbosa*, d'Orb., ×37.
" 12.— " *gramen*, d'Orb., ×37.
" 13.—*Bigenerina compressiuscula*, sp. nov., Holotype, ×37.
" 14.— " " " Paratype, ×37.
" 15.—*Spiroplecta sagittula*, Defr. sp., ×37.
" 16.— " *anceps*, Reuss sp., ×37.
" 17.—*Guembelina globulosa*, Ehrenberg sp., ×37.
" 18.— " *globifera*, Reuss sp., ×37.
" 19.— " *polystropha*, Reuss sp., ×37.
" 20.—*Gaudryina pupoides*, d'Orb., ×37.
" 21.— " *rugosa*, d'Orb., ×37.
" 22.—*Clavulina communis*, d'Orb., ×22.

Plate III.

23



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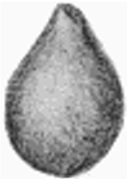

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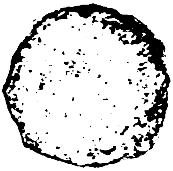

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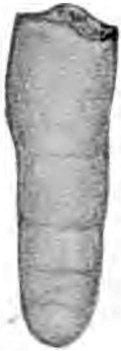

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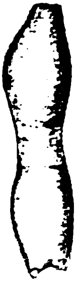

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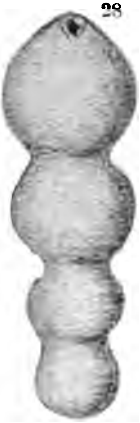

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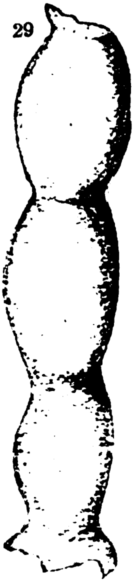

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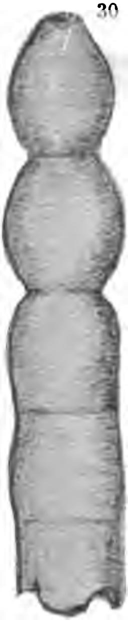

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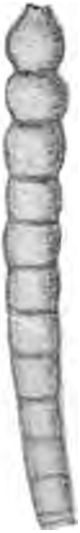

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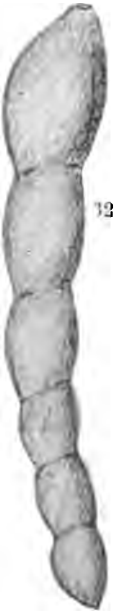

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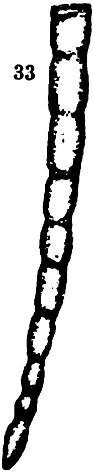
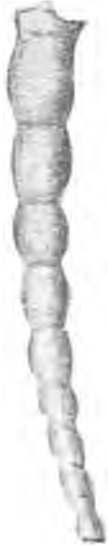


EXPLANATION OF PLATE III.

Fig 23.—*Lagena globosa*, Montagu sp., ×37.
„ 24.— „ *apiculata*, Reuss sp., ×37.
„ 25.— „ *aspera*, Reuss, ×37.
„ 26.—*Nodosaria* (*Dentalina*) *pauperata*, d'Orb. sp., ×37.
„ 27.— „ (*D.*) *distincta*, Reuss, ×37.
„ 28.— „ „ *soluta*, Reuss, ×37.
„ 29.— „ „ „ *var. discrepans*, Rss., ×37.
„ 30.— „ „ *annulata*, Rss., ×37.
„ 31.— „ „ „ Rss., ×18.
„ 32.— „ „ *communis*, d'Orb., ×37.
„ 33.— „ „ *consobrina*, d'Orb., var. *emaciata*, Rss., ×37.

Plate IV.

34



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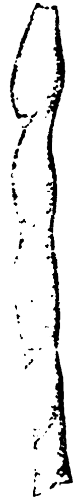

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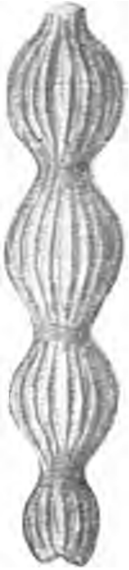

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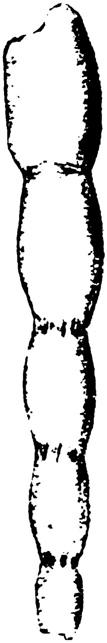

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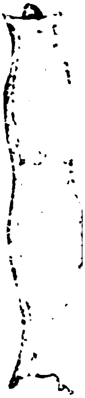

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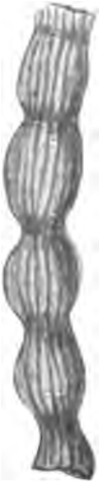

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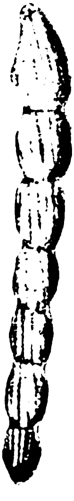

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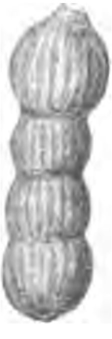

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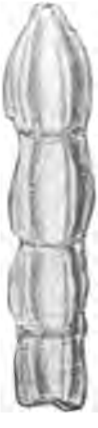

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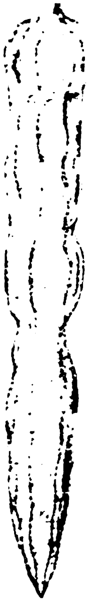
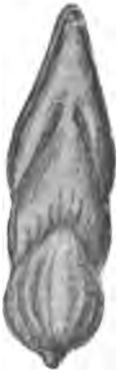


EXPLANATION OF PLATE IV.

Fig. 34.—*Nodosaria* (*D.*) *lorneiana*, d'Orb., × 37.
„ 35.— „ „ *filiformis*, d'Orb., × 37.
„ 36.— „ „ *retrorsa*, Rss. sp., × 37.
„ 37.— „ „ *intercellularis*, Brady, × 37.
„ 38.— „ „ *costellata*, Rss., × 37.
„ 39.— „ „ *obliqua*, Linné sp., × 37
„ 40.— „ „ *sulcata*, Nilsson., × 37.
„ 41.— „ „ *paupercula*, Rss., × 37.
„ 42.— „ *obscura*, Rss., × 37.
„ 43.— „ *prismatica*, Rss., × 37.

Plate V.

44



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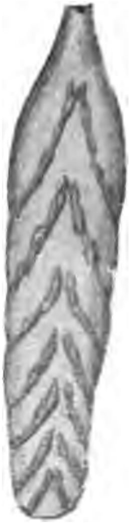

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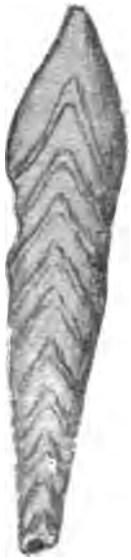

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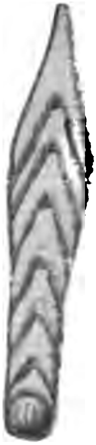

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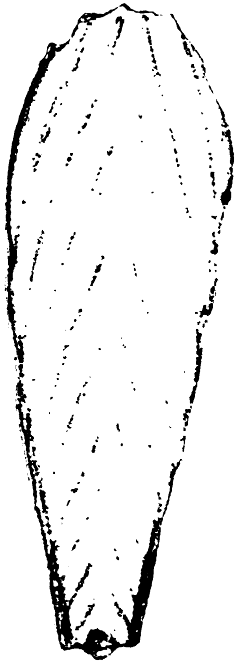

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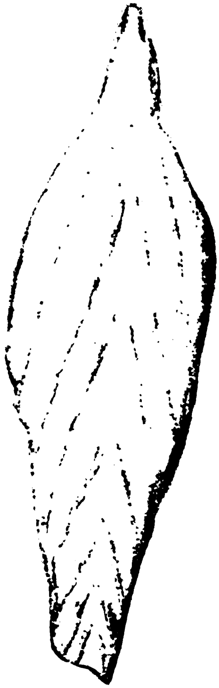

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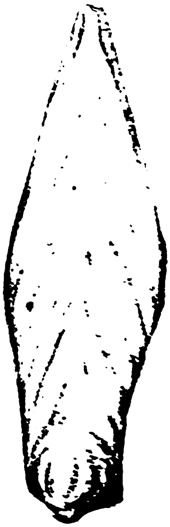


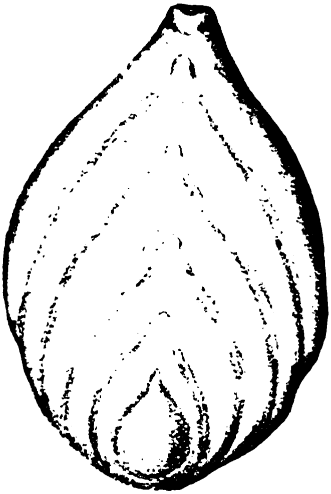
EXPLANATION OF PLATE V.

Fig. 44.—*Frondicularia ornata*, d'Orb., × 37.
„ 45.— „ *archiaciana*, d'Orb., × 37.
„ 46.— „ *chapmani*, Perner, × 18.
„ 47.— „ *lanceola*, Reuss, × 37.
„ 48.— „ *inversa*, Reuss, × 37.
„ 49.— „ „ „ × 37.
„ 50.— „ *apiculata*, Rss., × 37.

Plate VI.

51

57



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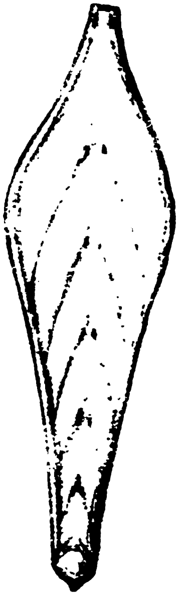

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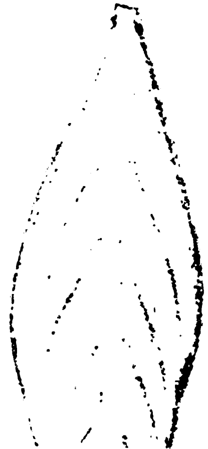

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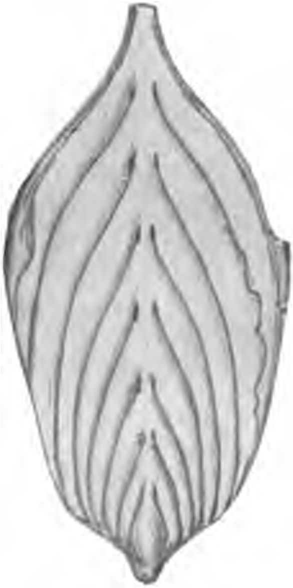
56

EXPLANATION OF PLATE VI.

Fig. 51.—*Frondicularia sherborni*, Perner, ×37.
„ 52.— „ *marginata*, Rss., ×37.
„ 53.— „ *decheni*, Rss., ×37.
„ 54.— „ *gaultina*, Rss., ×37.
„ 55.— „ „ ×37.
„ 56.— „ *ungeri*, Rss., ×37.
„ 57.— „ *perovata*, Chapman, ×37.

Plate VII.

58



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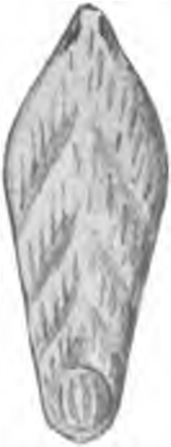

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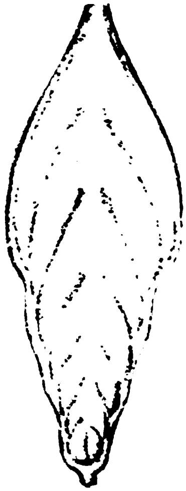

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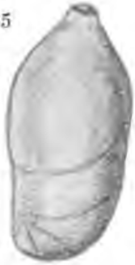

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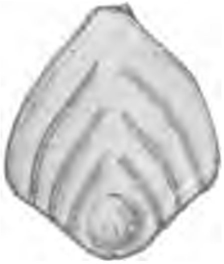

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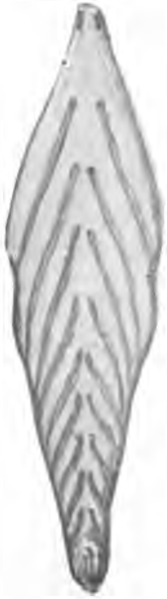

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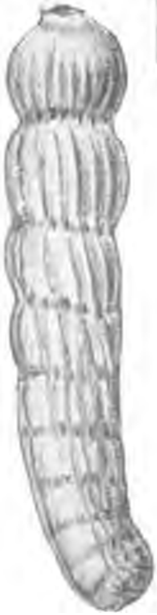

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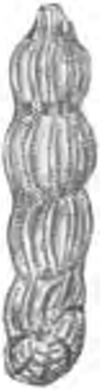

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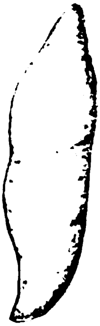
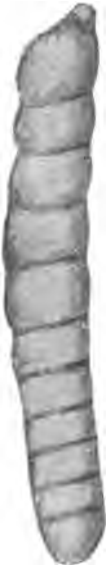


EXPLANATION OF PLATE VII.

Fig. 58.—***Frondicularia*** ***guestphalica***, Rss., ×37.
„ 59.— „ *intermittens*, Rss., ×37.
„ 60.— „ *cordai*, Rss., ×37.
„ 61.— „ *lanceolata*, Perner, ×37.
„ 62.— „ *angusta*, Nilsson, ×25.
„ 63.—*Marginulina* *costata*, Batsch sp., ×37.
„ 64.— „ „ var. with cristellarian commencement, ×37
„ 65.— „ *glabra*, d'Orb., ×37.
„ 66.— „ *inaequalis*, Reuss, ×37.

Plate VIII.

67



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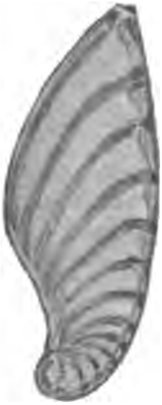

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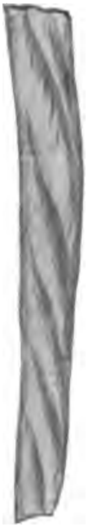

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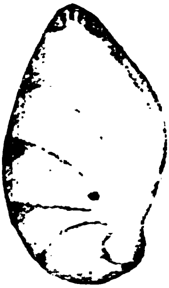

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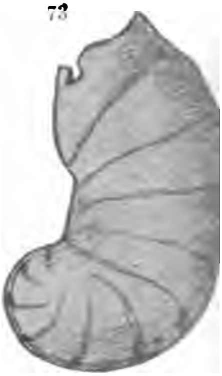

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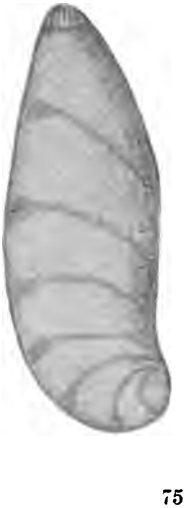

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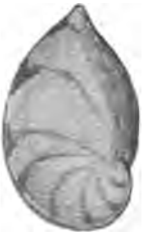

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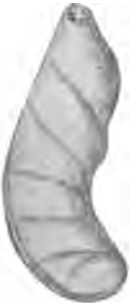

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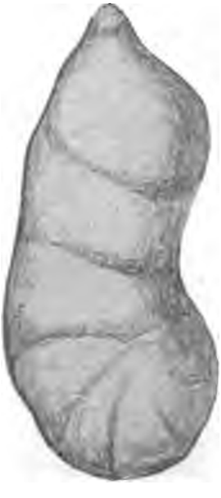

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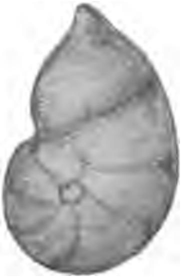

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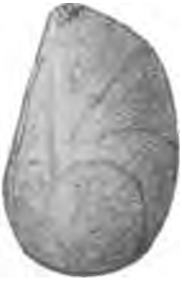
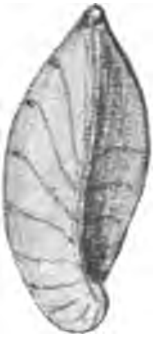


EXPLANATION OF PLATE VIII.

Fig. 67.—*Vaginulina* *legumen*, L. sp., ×24.
„ 68.— „ *comitina*, Berthelin, ×37.
„ 69.— „ *strigillata*, Reuss sp., ×37.
„ 70.—*Cristellaria* *planiuscula*, Reuss, ×37.
„ 71.— „ *lituola*, Rss., ×37.
„ 72.— „ *grata*, Rss., ×37.
„ 73.— „ *gladius*, Phillippi sp., ×37.
„ 74.— „ *acutauricularis*, F. and M. sp., ×37.
„ 75.— „ *ovalis*, Rss., ×37.
„ 76.— „ *schloenbachi*, Rss., ×37.
„ 77.— „ *bronni*, Roemer sp., ×37.

78



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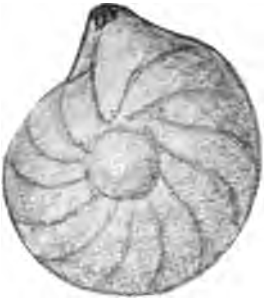

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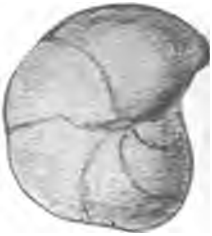

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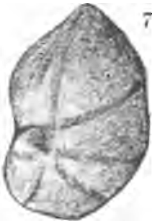

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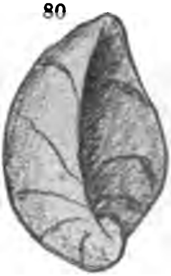

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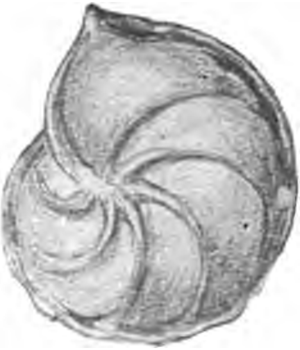

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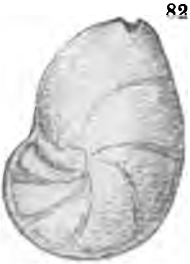

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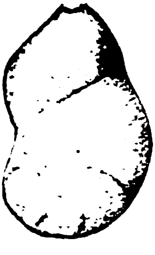

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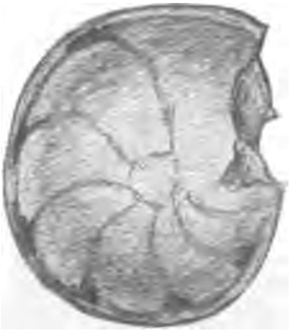

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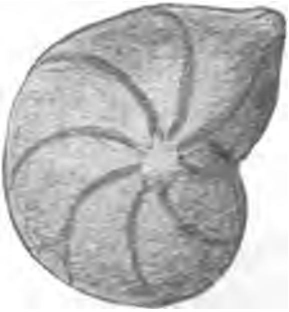
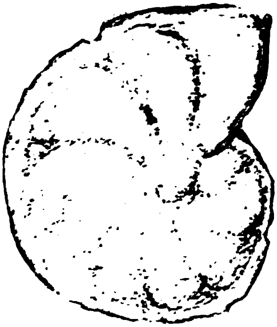


EXPLANATION OF PLATE IX.

Fig. 78.—*Cristellaria* *italica*, Defrance sp., ×37.
„ 79.— „ *navicula*, d'Orb., ×37.
„ 80.— „ *triangularis*, d'Orb., ×37.
„ 81.— „ *oligostegia*, Rss., ×37.
„ 82.— „ *gibba*, d'Orb., +37.
„ 83.— „ *articulata*, Rss., ×37.
„ 84.— „ *subalata*, Rss., ×37.
„ 85.— „ *gaultina*, Rss., ×37.
„ 86.— „ *rotulata*, Lam. sp., ×37.
„ 87.— „ „ var. *macrodiscus*, Rss., ×37.

Plate X.

88



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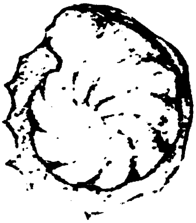

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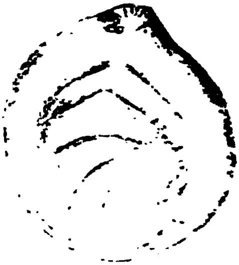

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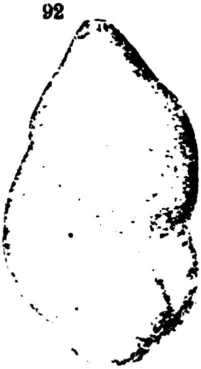

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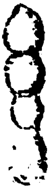

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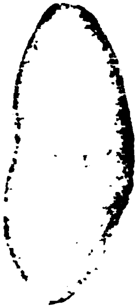

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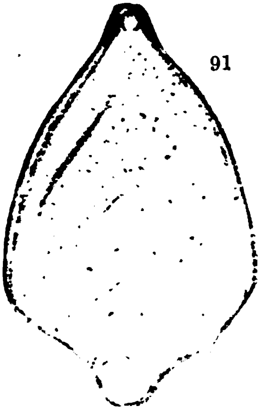

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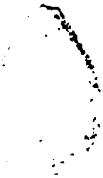

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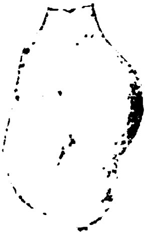

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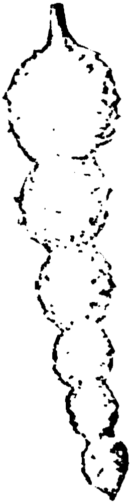

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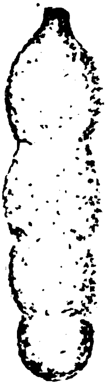

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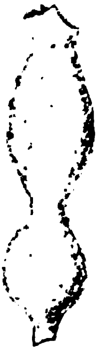

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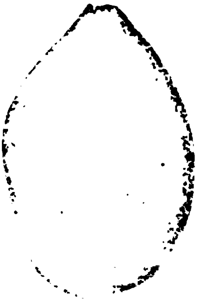
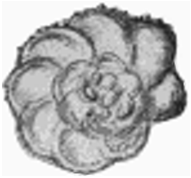


EXPLANATION OF PLATE X.

Fig. 88.—*Cristellaria circumcidanea*, Berthelin, ×24.
„ 89.— „ *diademata*, Berth., ×37.
„ 90.—*Flabellina rugosa*, d'Orb., ×37.
„ 91.— „ *interpunctata*, von der Marck., ×37.
„ 92.—*Polymorphina sororia*, Rss., ×37.
„ 93.— „ *angusta*, Egger, ×37.
„ 94.— „ *compressa*, d'Orb., ×37.
„ 95.— „ *communis*, d'Orb., ×37.
„ 96.— „ *lactea*, W. and J. sp., ×37.
„ 97.—*Sagraina maitlandiana*, sp. nov., ×37.
„ 98.— „ *asperula*, Chapman, ×37.
„ 99.— „ *monile*, sp. nov., ×37.
„ 100.—*Ramulina aculeata*, d'Orb., sp., ×37.

Plate IX.

103



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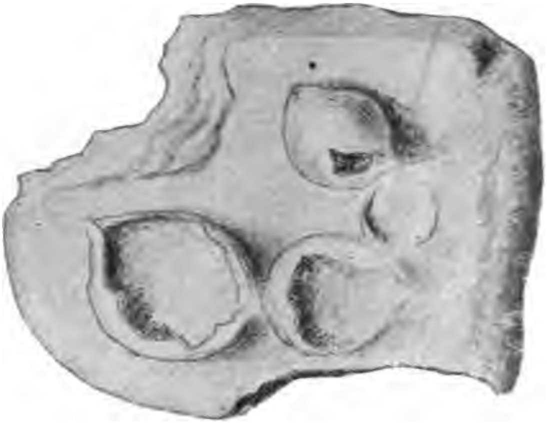

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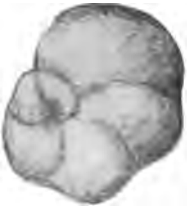
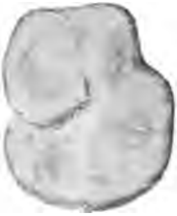
104a



104b



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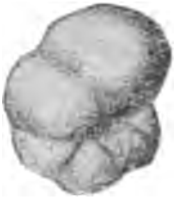

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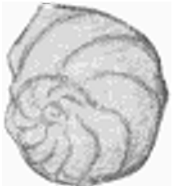

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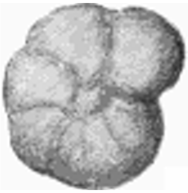

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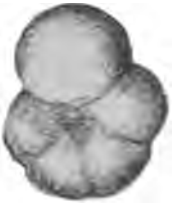

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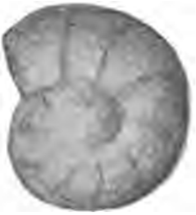

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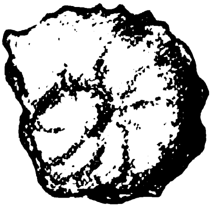

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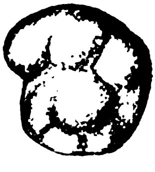


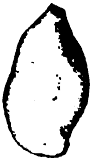
109a

EXPLANATION OF PLATE XI.

triwebbina laevis, Sollas sp., ×37.
obigerina cretacea, d'Orb., ×37.
„ *linnaeana*, d'Orb., ×37.
Truncatulina lobatula, W. and J. sp., ×37.
„ *convexa*, Reuss, ×37.
„ *wuellerstorfi*, Schwager sp., ×37.
nomalina ammonoides, Rss. sp., ×37.
ulvinulina elegans, d'Orb. sp., ×37.
„ *cordieriana*, d'Orb., sp., ×37.
„ *spinulifera*, Rss. sp., ×37.
otalia soldani, d'Orb., var. *nitida*, Rss., ×37.

Plate XII.

112



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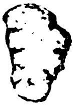

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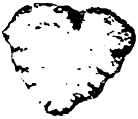

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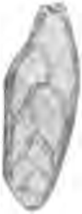

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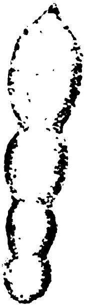

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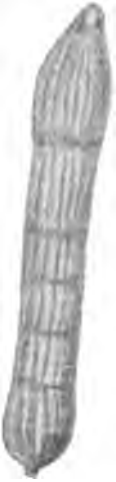

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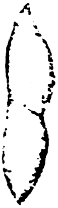

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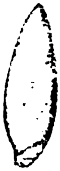

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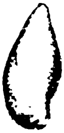

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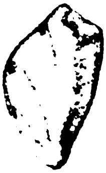

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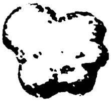

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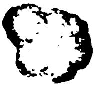

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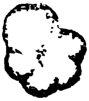

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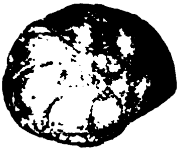

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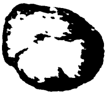
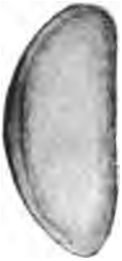


EXPLANATION OF PLATE XII.

iliolina venusta, Karrer sp., × 37.
piroplecta praelonga, Rss. sp., × 37.
„ *anceps*, Rss. sp., × 37.
ulimina variabilis, d'Orb., × 37.
olivina obsoleta, Eley sp., × 74.
odosaria subtertenuata, Schwager, × 37.
„ *perpusilla*, Chapman, × 74.
„ (*D.*) *legumen*, Reuss, × 37.
ristellaria tripleura, Rss., × 37.
„ *trunculata*, Berthelin, × 37.
„ *latifrons*, Brady, × 37.
lobigerina bulloides, d'Orb., × 37.
„ *cretacea*, d'Orb., × 37.
„ *aequilateralis*, Brady, × 37.
„ *marginata*, Rss., × 74.
phaeroidina bulloides, d'Orb., × 37.

Plate XIII.

3



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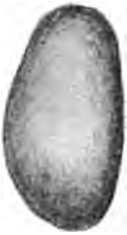

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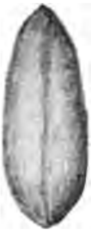
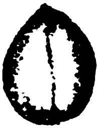


2c



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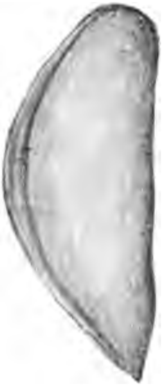

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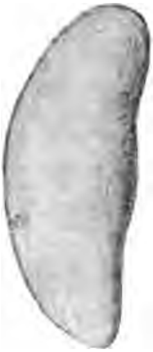

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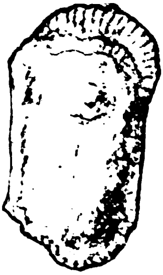

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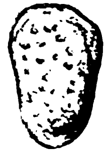

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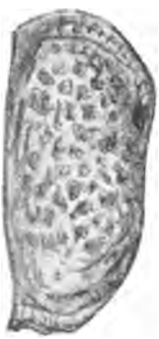

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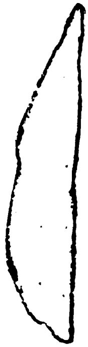

7c

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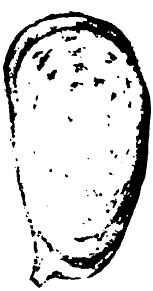


EXPLANATION OF PLATE XIII.

acypris siliqua, Jones and Hinde. Carapace seen from the right, ×37.

2c.—***Bythocypris howchiniana***, sp. nov. *a* Carapace seen from the right; *b* Edge view; *c* End view, ×37.

rdia arquata, Münster sp. Carapace seen from the right, ×37.

rocypris simplex, Chapman, var. ***africana***, nov. Right valve, ×37.

iereis ornatissima, Rss. sp., var. ***nuda***, Jones and Hinde. Right valve, ×37.

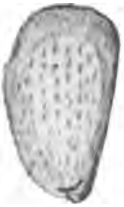
iere harrisiana, Jones, var. ***reticosa***, Jones and Hinde. Left valve, ×37.

7c.—***Cythere westraliensis***, sp. nov. *a*, Left valve; *b* Edge view; *c* End view, ×37.

iere westraliensis, sp. nov. Left valve, ? ♂, ×37.

Plate XIV.

9



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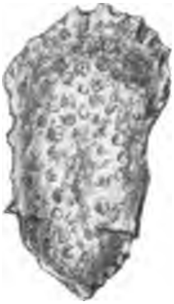

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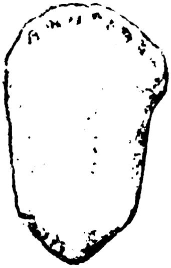

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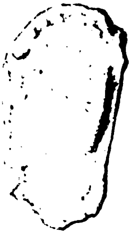

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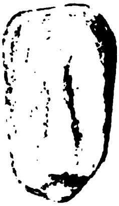

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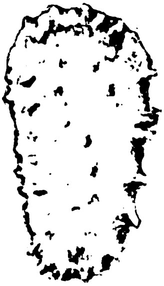

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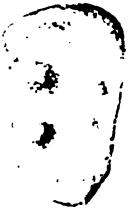

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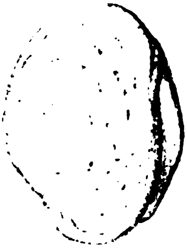

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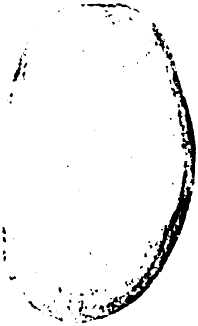

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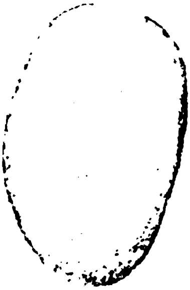

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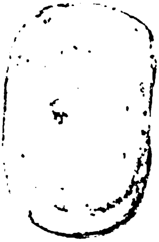
21



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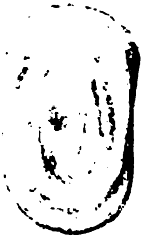
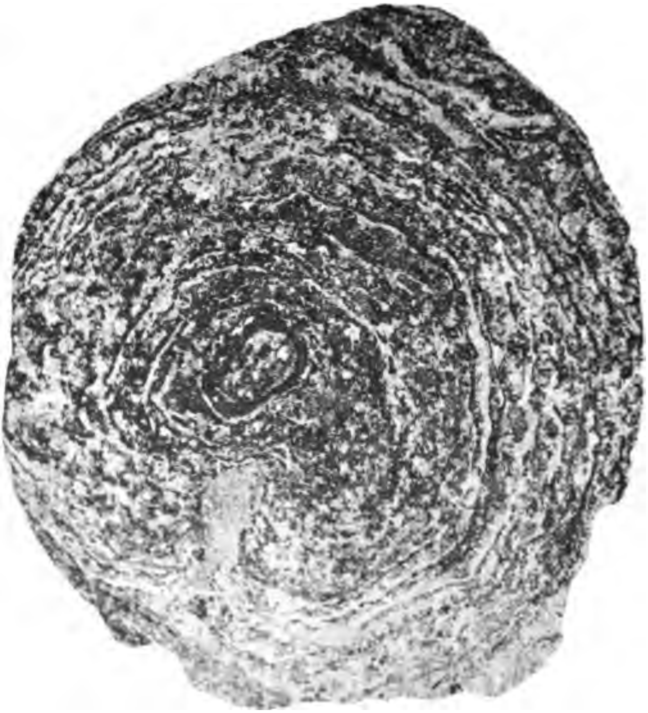


EXPLANATION OF PLATE XIV.

Fig. 9.—*Cythere lineatopunctata,* Chapman and Sherborn. Right valve, × 55.
" 10.—*Cythereis ornatissima,* Rss. sp., Right valve, × 37.
" 11.— " " var. *nuda,* Jones and Hinde. Left valve, × 37.
" 12.— " " var. *reticulata,* J. and H. Right valve, × 37.
" 13.— " " var. *stricta,* J. and H. Right valve, × 37.
" 14.—*Cythereis quadrilatera,* Roemer sp. Left valve, × 55.
" 15.—*Cythereis rudispinata,* Chapman and Sherborn. Left valve, × 37.
" 16.—*Cythereis tuberosa,* J. and H. Right valve, × 74.
" 17.—*Cytheropteron concentricum,* Reuss sp. Carapace seen from the right, × 37.
" 18.—*Cytherella muensteri,* Roemer sp. Left valve, × 37.
" 19.—*Cytherella ovata,* Roemer sp. Right valve, × 37.
" 20.—*Cytherella williamsoniana,* Jones. Left valve, × 37.
" 21.—*Cytherella williamsoniana,* var. *stricta,* J. and H. Left valve, × 37.
" 22.—*Cytherella chapmani,* Jones and Hinde. Left valve, × 37.

Plate XV.



Girvanella, sp.

Transverse section of a pellet, exhibiting a central nucleus and the concentric laminae of tubes—× 6 diam.

XII.—*Girvanella in The Cambrian Rocks*

OF

North-West Australia.

BY

R. ETHERIDGE, Jr.,

Curator, The Australian Museum, Sydney.

WITH ONE PLATE XV.

The obscure organism known as *Girvanella* has already been met with in the Cambrian of Victoria and South Australia, in certain Victorian Silurian limestones, and possibly also in the Carboniferous of New South Wales and Queensland.

For a full account of the affinities and distribution of *Girvanella* the reader is referred to Mr. F. Chapman's paper "On the Relationship of the Genus *Girvanella,* and its Occurrence in the Silurian limestones of Victoria." *

My attention was some time ago attracted by pellets, or small nodular masses, occurring in the Salterella Limestone of the Ord River, Kimberley. To the naked eye these appear either as oval or round masses of 20-25mm. approximately, and on closer inspection are found to be made up of concentric layers.

Thin slices prepared for the microscope at once revealed the nature of these masses—a peculiar arrangement of *Girvanella*-like tubes, layer upon layer, as in *Girvanella incrustans,* Bornemann,† occurring in the Cambrian of Sardinia. The tubes appear to form their own concentric layers, without the intervention of any layer-forming medium, and either repose on and intertwine with one another (so forming a lamina), or stand erect at right angles to the so-formed layer, or again indistinguishably entwined and twisted aggregations. But, no matter which of these three conditions exist, there is usually a free and unoccupied space between the top of one "lamina" and the base of that above. The edges of these spurious layers, cut in a section, are either in one plane or undulating. This degree of regularity does not exist throughout an entire pellet, but appears here and there, the remainder of its substance becoming a confused mass of tubes: still, on the whole this concentricity is certainly a marked feature of this Ord River form.

The pseudo-laminæ are produced in the first instance by a close agglomeration or intertwining of the tubes, but this close contact

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* Chapman: Proc. Austr. Assoc. Adv. Sci. for 1907. XI, 1908, p. 377.

† Bornemann: Vers. Camb. Schich. Insel Sardinien, 1886, p. 18, pl. 2, figs. 1 and 2.

soon breaks up, and the tubes then become as stated in a preceding paragraph. The inter-laminar spaces consist of a semi-clear magma, not matrix infilling, with tubes loosely scattered through it. So far as my power of magnification enables me to judge the tubes are entire and non-segmented, neither moniliform, nor annulate, or furcate; the diameter on the average is .017 mm.

The principal section revealed the presence of a foreign body, apparently a low form of coral life, as a nucleus, around which the *Girvanella* had grown; to its other characters, therefore, may be added that of an encrusting or enveloping nature.

The *Girvanella* detected in association with Archæocyathinæ in the South Australian Cambrian was noted as closely resembling the before-mentioned *G.* (*Siphonema*) *incrustans*, Bornemann, from the Baltic Silurian.[*] In this enveloping habit, the present form resembles *G. sinensis*, Yabe,[†] from China, and probably of Carboniferous age; this appears to me to differ but little from *G. incrustans*. Both envelop foreign bodies, both are concentric in structure, and seem to differ only in the matter of diameter, that of the first being .01 mm., and that of the second .015 to .02. The Kimberley *Girvanella*, on the other hand, differs from both in its uniform and non-moniliform tubes, and in size is practically intermediate between them. In this uniformity of size we see a close approach to the generic type, *G. problematica*, Nich. & Eth. fil,[‡] but here again size, 1.20-1.60 mm., steps in as an obstacle to identity. On the other hand, if the enveloping *Girvanella* of the Wenlock Limestone described by Mr. E. Wethered[§] be *G. problematica*, the connection between this and the Ord River form is increased by the remarkable variation in the tube diameter, .02, .03, .05 mm., etc.

I cannot satisfactorily identify this *Girvanella* with any other, the descriptions of which I have access to, and simply content myself by calling attention to its occurrence in the Cambrian of North-West Australia, and associated with *Salterella hardmani*, Eth. fil.

---

[*] Etheridge: Trans. R. Soc. S. Austr., XIII., 1890, p. 19.

[†] Yabe: Sci. Reports Tohoku Imp. Univ., 2d. Series (Geology), I., heft 1, 1912, pt. I., fig. 1.

[‡] Nicholson & Etheridge: Mon. Sil. Foss. Girvan, Fas. I., 1878, p. 23.

[§] Wethered: Quart. Jour. Geol. Soc., XLIX, 1893, pl. VI.

PALÆONTOLOGICAL CONTRIBUTIONS
TO
THE GEOLOGY OF WESTERN AUSTRALIA.

SERIES I.—BULLETIN 10, 1903.

(i.) Descriptions of Carboniferous Fossils from the Gascoyne District, Western Australia.—R. Etheridge, jun.

SERIES II.—BULLETIN 27, 1907.

(i.) Plant Remains from the Collie Coalfield. — R. Etheridge, jun.

(ii.) Notes on Fossils from the Collie Coalfields, Western Australia, in the collection of the National Museum, Melbourne.—F. Chapman, F.L.S.

(iii.) Fossils from Minginew, Irwin River Coalfield, collected by E. S. Simpson.—R Etheridge, jun.

(iv.) Descriptions of Carboniferous Fossils from the Irwin River, collected by Mr. C. F. P. Jackson.—R. Etheridge, jun.

(v.) Foraminifera from a Calacreous Marlstone, Gingin. – W. Howchin, F.G.S.

SERIES III.—BULLETIN 36, 1910.

(i.) On the Fossil Sponge Spicules in a Rock from the Deep Lead (?) at Princess Royal Township, Norseman Township.—Dr. Geo. J. Hinde, F.R.S.

(ii.) Some Fossil Plants from Western Australia. — E. A. Newell Arber, M.A., F.G.S. F.L.S.

(iii.) Oolitic Fossils from the Greenough River District.—R. Etheridge, jun.

(iv.) Sthenurus Occidentalis.—Ludwig Glauert, F.G.S.

(v.) A list of Western Australian Fossils systematically arranged.—Ludwig Glauert, F.G.S.

(vi.) Fossil Flora of Western Australia.—Ludwig Glauert, F.G.S.

(vii.) New Fossils from the Barker Gorge, Napier Range, Kimberley.—Ludwig Glauert, F.G.S.

(viii.) The Geological Age and Organic Remains of the Gingin Chalk.—Ludwig Glauert F.G.S.

SERIES IV.—BULLETIN 55, 1913.

(ix.) The Cretaceous Fossils of the Gingin "Chalk."—R. Etheridge jun.

SERIES V.—BULLETIN 58, 1914.

(x.) Western Australian Carboniferous Fossils, chiefly from Mount Marmion, Lennard River, West Kimberley.—R. Etheridge, jun.

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1917.

WESTERN AUSTRALIA.

GEOLOGICAL SURVEY.

BULLETIN No. 73.

The Geology
of
The North Coolgardie Goldfield.

PART I.

The Yerilla District,

BY

C. SIDNEY HONMAN, B.M.E. (Melb.),
Field Geologist.

With Appendices

BY

R. A. FARQUHARSON, M.A., M.Sc., and J. T. JUTSON.

Issued under the Authority of
THE HON. R. T. ROBINSON, K.C., M.L.A., MINISTER FOR MINES.

WITH EIGHT PLATES AND THIRTY-SEVEN FIGURES.

PERTH:
BY AUTHORITY: FRED WM. SIMPSON, CONTROLLER OF PRINTING.

1917.

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PREFATORY NOTE.

This Bulletin forms one of the series designed to be descriptive of the North Coolgardie Goldfield; it deals exclusively with the Yerilla District, which forms the easternmost portion of the field.

Although mining in the district has been carried on since the year 1895, very little ore has been raised; the deepest workings nowhere exceed 400 feet, and efforts have been expended in many places. The total quantity of ore raised and milled in the district up to the close of 1915 amounts to 209,529 tons, yielding 188,502 ozs. of fine gold, in addition to which 8,806 ozs. of alluvial, dollied, and specimen gold were reported to the Government.

The area covered by the report amounts to about 5,000 square miles, and the field work occupied Mr. Honman, the geologist entrusted with the work, about ten months.

The country embraced by the Survey falls within portions of the 40-chain lithographs L26, L27, L28, L50, and L90, issued by the Department of Mines, and sheets 33 and 34 of the 300-chain series of the Department of Lands and Surveys.

The frontispiece to this Bulletin is a general map of the whole of the North Coolgardie Goldfield, as legally defined, and upon it has been shown the present condition of our knowledge of the geology.

An important feature in the geology of the district is the occurrence of a continuous belt of sedimentary rocks, about two or three miles in width, which has a horizontal extent of about 25 miles and a general strike of north-west and south-east. The beds are in all probability continuous with that series which occurs to the south-eastwards in the vicinity of Gilgarna (Lands Dept. 300-chain litho. No. 26). The sediments consist of conglomerates, fine-grained grits and phyllites, intersected by dykes of porphyry. It has not been found possible to obtain a reliable basis for an estimate of the thickness of the sedimentary series to be made; it would, however, appear to be considerable. The series is traversed by quartz reefs which, where observed, were found to lie parallel to the bedding planes of the sediments; the reefs have, however, only yielded 295.45 ozs. of fine gold, or with an average of 1.35 ozs. per ton of ore milled. No definite evidence has been discovered in the district as to the stratigraphical position of the series, though there seem sound reasons for believing it to be Pre-Cambrian.

Occurring in the district is the belt of ferruginous cherts or quartzites (jaspilites), which has been followed for a distance of about 50 miles in a general north-westerly direction. The belt first makes its appearance in the southern portion of the district, to the west of Pingin, and can be followed without interruption northwards via Edjudina and Mount Millicent, ultimately disappearing on the shores of Lake Carey to the eastward of Yundamindera. The beds are arranged in a series of steeply inclined anticlinal folds, the trend of which is parallel to that of the strata forming the Yilgangi belt. Some of the greenstones, believed to be basic lava-flows, with which the jaspilites are associated, exhibit a marked bedded structure, and it may be that some are of sedimentary origin. Interbedded with these is a graphitic shale, resulting from the contact metamorphism of an aluminous carbonaceous shale.

Bands of serpentine and dolomite occur in parallel belts which coincide in strike with the jaspilites and their associates; these serpentinous rocks may perhaps owe their origin to the alteration of dolomitic limestones associated with the other metamorphic rocks.

The beds of which the Pingin-Edjudina belt is composed range from almost pure quartz, through jaspilite, to high-grade hematite, with a little magnetite. Analyses of these ferruginous rocks show them all to contain a high percentage of silica and a relatively low iron content; many of the deposits, however, could readily be concentrated to high-grade iron ores, though their geographical position puts them under present conditions entirely beyond the reach of commercial enterprise.

A very large area of the district is made up of granite and rocks genetically allied thereto. The granite occurs in three distinct belts which have, when viewed broadly, a general parallelism one to the other, north-westerly. The central granite belt, which varies very much in its lithological constitution, extends without interruption from Calvally Soak north-westwards to Yundamindera, has in many places undergone dynamic deformation resulting in the production of granitic gneiss.

In many localities along the marginal contact with the surrounding greenstones there is a marked increase in basicity, producing rocks containing large quantities of hornblende.

There is, in addition to the above, a series of ancient amygdaloidal lavas, with tuffs and agglomerates, into which dolerite penetrates as small dykes.

A noticeable economic feature in the Yerilla District is the grouping of the gold-bearing quartz reefs in the greenstone, in the vicinity of the intrusive granite. Some of the quartz reefs may be found to pass in depth out of the greenstone into the granite, and as they appear to have been formed after the intrusion of it, the reefs need not be expected to disappear on meeting a different country rock. Such evidence as is available seems to indicate that the gold occurring in the reefs and lodes owed its origin to magmatic waters, emanating from the granitic magma in which it was originally contained.

The mining centres, in nearly all cases, occur in those areas which have undergone considerable dynamic disturbance, represented by shearing and faulting.

The quartz reefs range from veinlets a fraction of an inch in width to solid veins sometimes as much as 30 feet thick; they dip at steep angles, and as a rule conform closely both in dip and strike to the structural planes of the enclosing rocks.

The mineralogy of the gold ores is simple, quartz being the predominant gangue mineral, which is mostly uniform in character. Sericite, galena, and pyrites are not unusual associates of the gold.

While, as pointed out in 1903, after a careful reconnaissance in the district, it is by no means improbable that there are ore deposits which yet await discovery, the prospects for any important addition to the known gold-bearing localities is not by any means hopeful. Attention might, however, be given to the search for new ore-bodies along the trend of the two main fault lines which traverse the district. If the gold production is to be maintained, or even increased, it is rather to be looked for in the mines already in existence than in the discovery of new ones.

The statistics of gold production have been compiled from data furnished by the Statistical branch of the Mines Department, and the plans and sections of the underground workings have been based on the plans which the mine owners lodge with the Government in compliance with the Mines Regulation Act.

Mr. Honman having joined the Expeditionary Forces for service at the Front, was not able to devote as much time to the preparation of the report on his field work as would otherwise have been the case.

A Gibb Maitland

GOVERNMENT GEOLOGIST.

Geological Survey Office,
Perth, 22nd February, 1917.

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OLOGICAL SURVEY OF WESTERN AUSTRALIA.

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* Serving with the Expeditionary Forces.

THE GEOLOGY OF THE NORTH COOLGARDIE GOLDFIELD.

PART I.

THE YERILLA DISTRICT.

INTRODUCTION.

The Yerilla District is the easternmost portion of the North Coolgardie Goldfield, and is bounded on the north by the Mt. Margaret Goldfield; on the south by the North-East Coolgardie Goldfield; on the west by the Menzies and Niagara Districts of the North Coolgardie Goldfield; and on the east by an indefinite tract of sand and spinifex. The area surveyed comprises a square block of country, roughly, 70 miles by 70 miles, and covers an area of 5,000 square miles.

The following mining centres are included in the district:—

Linden, including Mt. Howe and Mt. Celia;
Edjudina and Yarri;
Pingin;
Yundamindera (The Granites), including Pyke's Hollow,
Pennyweight Point, and Eucalyptus; and
Yerilla, including Mt. Remarkable.

The field operations were based on the following plan:—

(1) A complete delineation of the different class of rocks, showing their relation to the distribution of gold and other minerals.

(2) A more detailed study of the different mining centres.

(3) An examination of all working mines and abandoned mines which might deserve further attention.

In connection with the east portion of my work, I have to thank the mine managers and prospectors of the district for valuable information and assistance.

The field work was commenced towards the end of 1915 and continued for the greater part of 1916. Upon completion in October, 1916, 10 months in all had been spent in the field.

In 1903, Mr. A. Gibb Maitland made a tour of the Yerill District. In his report Mr. Maitland generalises upon the geolog of the various centres, and besides describing the mines as the existed at that time, he has drawn a geological sketch map Yarri and Edjudina.

In 1903 and 1905, Mr. A. Montgomery visited and reported the state of mining at Yarri, Edjudina, Pingin, and Yerilla.

Mr. Maitland's report appeared as Bulletin No. 11 of the Ge logical Survey Department, and Mr. Montgomery's in the Annu Reports of the Mines Department for the years 1903 and 1905.

The total production of gold from the Yerilla District to th end of 1915, as reported to the Mines Department, is as follows:– Alluvial, 1,238.75 fine ozs. Dollied and specimens, 7,567.99 fin ozs. Ore treated, 209,529.92 tons (2,240lbs.) Gold therefro 183,502 fine ozs. This gives an average of 17.5dwts. for o crushed.

The total production of the Yerilla district represents 10.5 pe cent. of the total production of the North Coolgardie Goldfiel which is 6.5 per cent. of the total gold production of the Stat therefore, the total production of the Yerilla District is less tha 1 per cent. of the total production of the State.

Appended to this report is a complete list of all the mines an their records to the end of 1915, which has been kindly supplie by the Statistical branch of the Mines Department.

For minerals other than gold, the production is *nil,* exclusiv of 63 ozs. of silver produced with the gold.

I have to thank Mr. Farquharson for a number of petrologica determinations. His notes form an appendix (ii.) to this report.

PHYSICAL FEATURES.

The physiography of the Yerilla District is similar to other parts of the Eastern Goldfields which have been more fully described elsewhere at various times by the officers of the Geological Survey.

The physical features are best divided into three groups:—

(1) The *Higher-land.*
(2) The *Lower-land, or Plains.*
(3) *The Dry Salt-lake country.*

All three more or less encroach on each other.

(1) The *Higher-land* of this district may be said to be divided into four belts, by the three dry lakes which cross the district in a north-west and south-east direction, viz., Lakes Carey, Raeside, and Rebecca. These higher-land belts may be named as follows:—

(a) The Mt. Wilga higher-land.
(b) The Yundamindera-Linden higher-land.
(c) The Yerilla-Edjudina higher-land.
(d) The Carr-Boyd Rock-Mt. Ballona higher-land.

Generally speaking, these belts of higher-land are parallel to each other and the dry lakes, but cross the general strike of rocks which is north-north-west, and that usually prevailing in the Eastern Goldfields.

Taking the physiography of the higher-land generally, apart from their parallelism to the lakes, the ranges and other physical features individually conform to the geological structure of the country rocks. These cross the higher-land belts obliquely in a north-north-west direction and conform to the strike of the different kinds of greenstones, the hematite quartzites and the dominant trend of the schistosity.

It would appear as if the salt lakes belonged to a different cycle of erosion uninfluenced by the geological structure of the rocks.

The principal land-marks which stand out from an otherwise monotonously flat landscape, are the Mts. Kilkenny, Kilmore, and Kildare Ranges; ridges along the west side of Lake Raeside; the Mt. Catherine Ranges; Mt. Boyce; the Edjudina Ranges, of which Yaboo Hill is the most prominent peak; the extension of the Edjudina Ranges northwards, the highest points being Mts. Millicent, Howe, Hornett, and Florence; the Mt. Percy Ranges (a scattered group of hills); the quartz blows south of Yundamindera; Mt. Colindina, which is the edge of the Yundamindera plateau; Mt. Celia, south of Linden; and the Mt. Wilga Range, north-east of Linden.

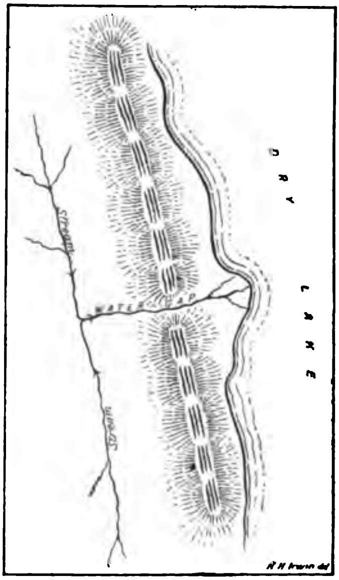
The Edjudina and Mt. Millicent Ranges are noteworthy for their persistency and uniformity of structure. The geological significance of these ranges was first noted by Mr. Maitland in 1903 and later by Mr. Montgomery. Mr. Maitland pointed out that they had been followed for 50 miles and would probably extend as far as Mt. Morgans. My mapping confirms this, and they can be traced from the south boundary of the district to the shores of Lake Carey, a distance of over 60 miles, and there is no doubt that they are continuous with Mt. Margaret, which is a prominent range of the same rocks on the north side of Lake Carey.

An interesting feature of the Edjudina Ranges is the existence of a number of distinct water-gaps. One in particular is a very fine example, and is known locally as "The Gap." From the summit of the range the T-shaped head of the water courses can be distinctly seen (See Fig. 1).

(2) The *Lower-land* constitutes the more or less level tract of country which intervenes between the higher-land and the lake country. A great extent of this lower-land is, in my opinion, alluvium, especially in proximity to the northern shore of the lakes. Though in places bare outcrops do occur, a great many of them are cement-covered, which can form a hard capping to alluvium as

well as country rock. Proof of this can be had at Yundamindera, where two shafts have been sunk in "made" ground to a depth of 45 feet and over 50 feet respectively. A cross-cut was cut from one shaft along the bottom of the wash and under a creek, in which hard cement was showing. This cement, although being the cap of an alluvial deposit, is unrecognisable from the laterite capping covering granite and known to have been derived from the granite. This is most important, as showing how easily a cement covering alluvial ground may be mistaken for bed rock, and hence the difficulty of defining and recognising the deep ground in any locality from surface indications. It follows that there must be many localities in which the deep ground is thus masked by cement.

Fig. 1.



Bird's eye view of the Gap about 10 miles N.N.W. of Edjudina.

All wells that have been sunk on the lower-land intervening between the Salt Lakes and the higher-land are in alluvium, *e.g.*, the Government Well, three and a-half miles west of French's Soak, and two wells three and six miles north-west of it. Marloo well and another north-west of Mt. Percy, and a well five miles north-east of Mt. Millicent. None of these wells have bottomed on to bed rock and the deepest is 45 feet. This proves conclusively that a great deal of the lower-land is deep ground.

The lower-land in proximity to the lakes is wind swept and covered with blown sand, and close to the lake with sand dunes.

(3) The *Dry-Lake Country* is of the usual type occurring on Eastern Goldfields, with, however, some very marked characteristics.

There are three lines of lake country, all running north-west and south-east, namely:—

Lake Carey.
Lake Raeside.
Lake Rebecca.

These lakes have significant characteristics, which are common to each.

(a) All have roughly parallel courses.

(b) All have an escarpement on the west and sand dunes on the east.

(c) All are rock-floored on west side and have a fair depth (unknown) of alluvium on the east side. A six-foot rod can be pushed into lake silt without touching bed rock on the east side.

The great length and narrow course of Lake Raeside suggest that it is the stagnant remains of an old river. Though not flowing now, a very complete system of tributaries runs into it. These tributaries are usually dry, but are full flowing streams after rain. A very good view of minor tributary streams can be obtained from the summit of Mt. Millicent, from where one can see as many as seven parallel, perfectly serpentine water courses flowing into a main tributary, which flows into an arm of Lake Raeside, skirting eastern side of the range. (See Fig. 2).

The rock flooring on the west side of the lake is probably due to "migration." This process is fully described by Mr. Jutson in his Physiography of Western Australia, Bulletin 61. The extraordinarily level character of the lake surface is probably due to water action causing decomposition to a hydrostatic level, determined by the state of soakage of the lake, and subsequent drying, disintegration and removal by the wind. If the levelling were alone due to wind action, *i.e.*, planing down by sand particles blown across the surface, one would expect an uneven surface due to the differential action of the sand particles instead of a surface as level as a hydrostatic plane. Away from the rock-flooring on the eastern side of the lake, no idea of the depth of the overburden can be arrived at, except that it is probably deeper than the wash found in the wells in the lower-land to the east of the lakes, *i.e.*, over 50 feet deep east of Lake Raeside. It is also quite possible on a narrow lake to find rock-flooring right across its surface, in which case the distance the lake has ''migrated,'' has exceeded the width of the lake, with the result that the original lake surface

Fig. 2.

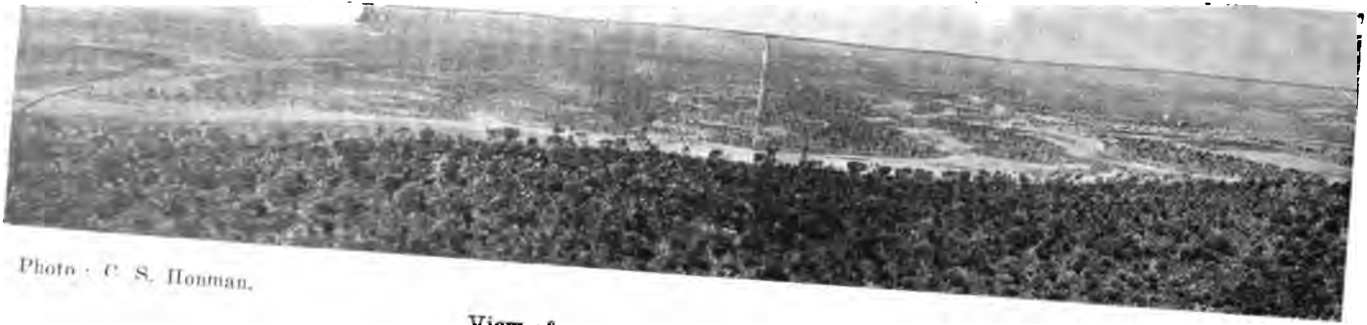


Photo : C. S. Honman.

View of country east of Mt. Millicent.

Negs. 1495-6.

and its deep ground have been covered by sand dunes and other æolian deposits.

The fact that the rock flooring is on the west side, in the case of every lake in the district, is probably due to the prevailing direction of the wind being from the south-west.

GENERAL GEOLOGY.

Succession.—The rocks of the Yerilla District belong to the same series as the rest of the Eastern Goldfields, which have so far been classified as of Pre-Cambrian age. Of all the Pre-Cambrian rocks of other parts of the world, they seem most to resemble the Huronian rocks of the Lake Superior Region of America, especially the greenstone schists of the Marquette iron-bearing district. The sedimentary series being younger, are probably contemporaneous with the Keewatin or Keeweenawan series of that region.

The general succession of the rocks of the Yerilla District is as

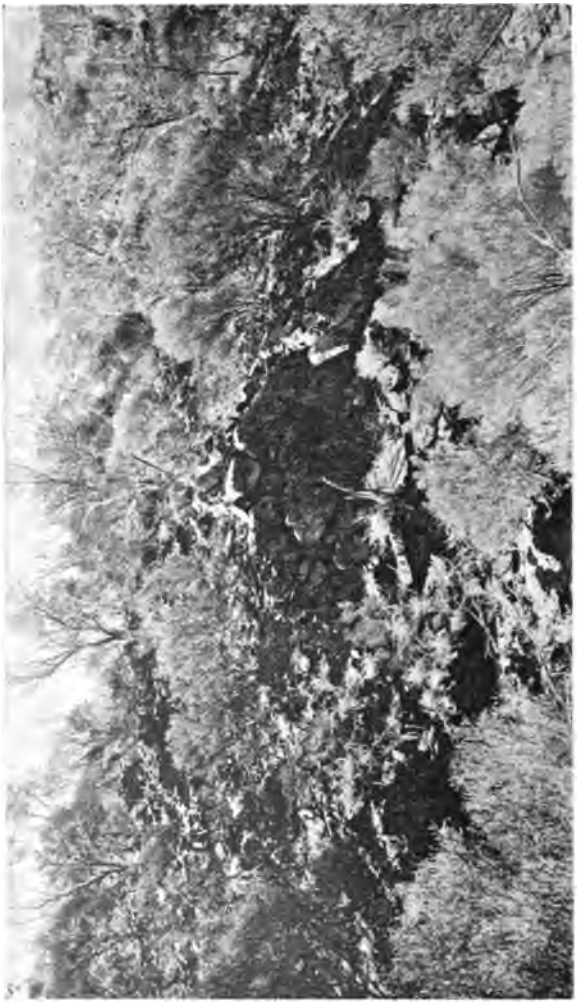
Recent		Shallow Alluvium Aeolian Deposits Cements and Laterites
Kanowna Series		Quartzites Deep Alluvium
Pre-Cambrian or Proterozoic	Intrusive	Dolerite Pegmatite Porphyry Granite, Granodiorite and Syenite Peridotites and Derivatives Gabbros and Epidiorites
	Newer Sediments	Conglomerates Arkoses Shales Tuffs and Ashes
	Volcanic	Greenstone schists Amygdaloids Agglomerates Porphyrites Rhyolites
	Older Sediments	Ferruginous Quartzites (Jaspers)
Archæozoic		Gneiss

DESCRIPTIVE GEOLOGY.

Gneiss: The oldest rocks of the district must necessarily be the ancient basement upon which the volcanic rocks composing the greenstones were spread out. It is most probable that this ancient basement has been completely changed to granite and gneiss. But it is possible that some of the gneissic areas which are scattered throughout the granites may be the relics of such an ancient basement. There are some marginal gneisses which may, however, have been derived from granite by pressure.

The gneiss is generally intruded by granite dykes and pegmatites which favour their being of older age than the main granite bosses, which are less intruded by pegmatites.

Fig. 3.



Anticlinal structure north of Mt. Millicent.

Photo.: C. S. Honman. Neg. 1286.

It is also significant that the gneisses are sometimes *garnetiferous*, showing that they have been subjected to contact metamorphism. For instance, at Kirgilla Rock, east of Pingin, where garnets occur in bands of the gneiss.

Older Sediments: Ferruginous Quartzites (Jaspers). These are bands of quartzite of the usual type which outcrop as parallel ridges interbedded with greenstone schists. The boundaries of the quartzites in all cases observed were sharp and regular. For the most part the banding is not contorted, being perfectly straight except at the summits of the highest ridges, where an anticlinal structure is observable. The caps of these anticlines probably account for the prominence of these ridges helping to resist denudation.

Fig. 4.

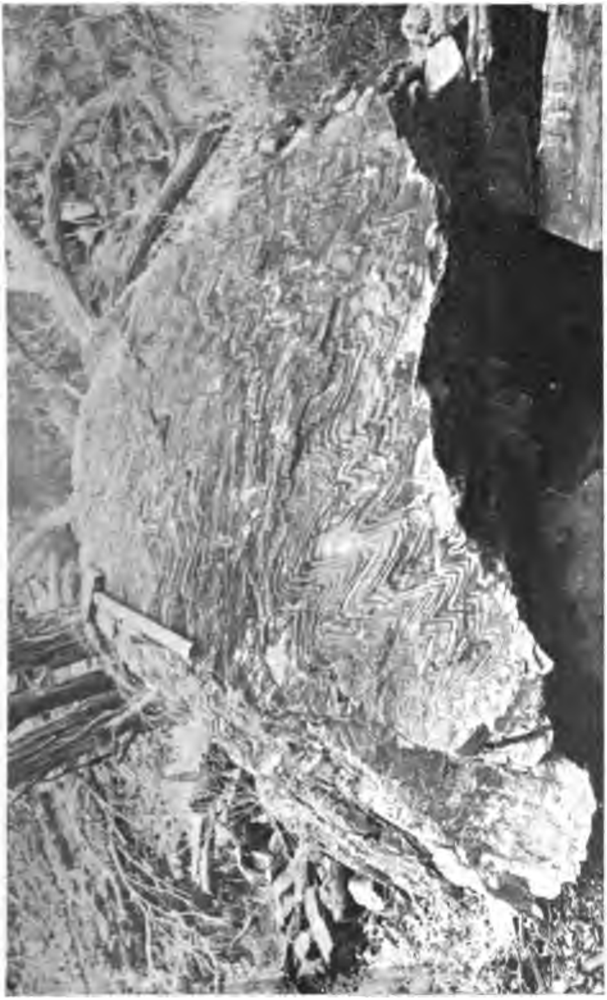


Photo.: C. S. Honman. Neg. 1293.

Contortions in block of Ferruginous Quartzite near Mt. Millicent.

Wherever contortion occurs two legs can be made out with schists intervening as though forming the legs of an anticline, which is much contorted at the arch.

The quartzites vary from totally siliceous to bands of almost pure hematite, and vary in colour from white through all shades of pink to vermilion and black.

A very noticeable anticlinal arch occurs half a mile north of Mt. Millicent (see Fig. 3). The arch is contorted as in Fig. 4, and the legs are perfectly straight.

I am of opinion that these bands of quartzite are of sedimentary origin, being sediments conformable with volcanic beds since changed by pressure to greenstone schists.

The following facts favour a sedimentary origin:—

(1) Wonderfully uniform banding.

(2) Continuous strike for distances corresponding to the occurrence of supposed interbedded greenstones for 70 miles.

(3) Parallelism with known undoubted sediments and conglomerates for a distance of over 30 miles, showing that it is not impossible to have sediments so persistent and uniform for such a great distance in the district.

(4) The beds have been intruded by granite and therefore formed before the granite.

(5) All the shearing, faulting and fracturing to which the district has been subjected has also been imparted to the quartzites.

(6) Perfectly sharp margin with schists.

(7) Anticline structure proved to be present, and distortion at the arch proving that the shearing that produced the schist was subsequent to the quartzites.

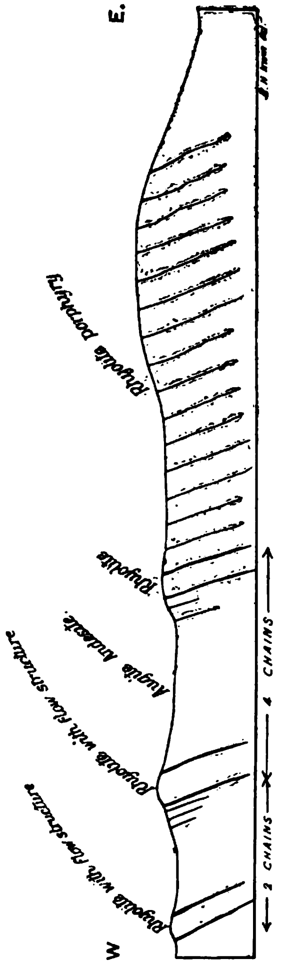
Mr. Maitland, in his report on the district in 1903, favours a shear zone for the quartzites, but, as he pointed out, with the knowledge possessed at that time it was difficult to form any precise opinion. Mr. Montgomery supports Mr. Maitland's idea.

Since Mr. Maitland visited the district and during the course of this survey much further knowledge has been gained as to the structure of the quartzite ridges, and also the relation of the associated rocks to the quartzites, and it can be demonstrated without a doubt that all visible shearing, schistosity, distortion, faulting and fracturing of the rocks have been subsequent to the formation of the quartzites.

There is another ferruginous quartzite band which passes through Mt. Ruth and Trigonometrical Stations R1 and R2 and southwards parallel to the conglomerate series nearly as far as Mulgabbie. This is more irregular than the Edjudina quartzites and a good deal of fissuring has taken place along the line. Though at places it is uniformly enough banded to be of sedimentary origin, it is generally so fissured and fractured as to appear to be a zone of shearing impregnated with quartz and ironstone.

Near Yandangerie, this lode is capped with goethite which is very vuggy and has been leached of some soluble mineral. It is probable that this outcrop caps a sulphide lode as pointed out by Mr. Simpson in reference to goethite gossans occurring elsewhere on the goldfields. (See Mineral specimen $[\frac{1}{380}]$.)

Fig. 5.



Section about one mile south of the 17-mile post, on the Yundamindera-Linden road.

The ferruginous and siliceous character of the quartzit probably secondary and due to concentration at the surface o

Fig. 6.

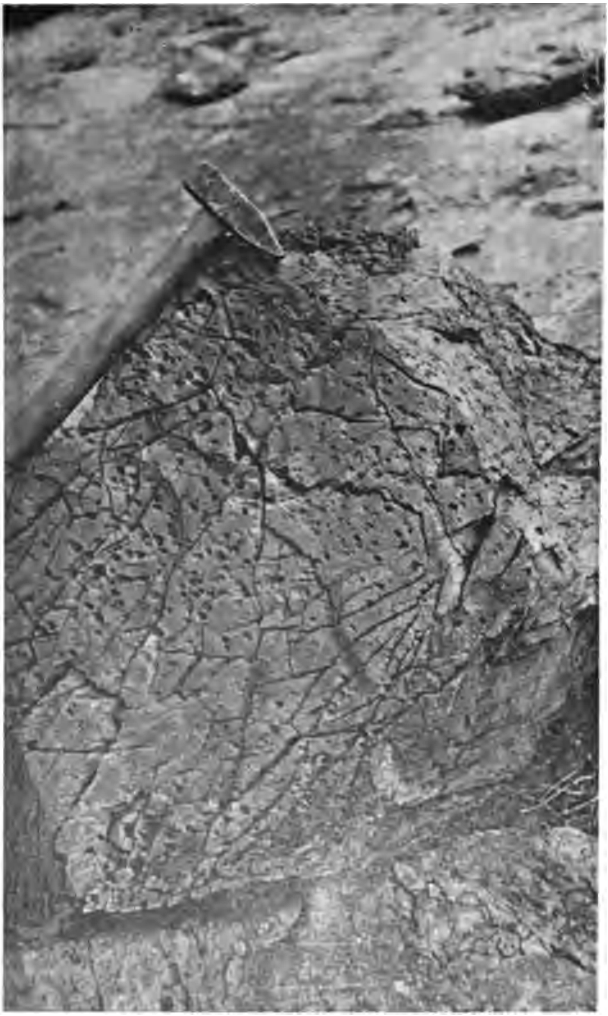


Photo.: C. S. Honman. Neg. 1292.

Shrinkage cracks and vesicular structure in Greenstone, east of Yerilla on Lake Raeside.

iron and silica of the sedimentary beds. The beds may have ashes or black shales before the concentration of silica and iro the surface. Black shales and ash beds are a common occurrence in a volcanic series.

VOLCANIC SERIES.

By far the greater proportion of these rocks are greenstones, the acid and intermediate representatives occurring in very subordinate amount.

Rhyolites and Porphyrites.—These rocks are much less widely distributed than the greenstones. They appear to be flows contemporaneous with the basic lavas now represented by the greenstones and occur as narrow bands in the greenstone.

They are generally amygdaloidal, sometimes show flow structure, and are generally schistose.

The most extensive occurrences of the rhyolite is between the 17 mile and 20 mile on the Yundamindera-Linden Road. They form a belt roughly one and a half miles wide strikingly parallel with the greenstones, viz., N.N.W. A narrow occurrence can be seen at the 11 mile on the same road, showing distinct spherulitic structure associated with a band of conglomerate.

The rhyolitic series is associated with jasperoid bands which appear to be interbedded with them. For the most part they are massive, but show straight parallel banding. They are also interbedded with the more basic flows and with slates. A typical section is shown in Fig. 5.

The porphyrites are represented most extensively at Mt. Remarkable, about 10 miles north of Yerilla. The belt is about three miles wide, is strongly foliated and amygdaloidal. It appears to extend southwards for many miles and evidently represents an intermediate series of lava flows contemporaneous with the greenstones. There are also some quartz-porphyries at Mt. Remarkable, and some of the porphyrites very much approach a porphyry in composition.

Southwards a similar belt occurs as a ridge of hills a couple of miles east of B 58, as sheared quartz-porphyry.

Still further south at the 30-mile well on the Edjudina Road a granite tongue has invaded the sheared porphyry from the Calvally Batholith.

Interbedded with the rhyolites near the 17 mile post on the Yundamindera-Linden Road there occurs a rock which has been described by the petrologist as a felspathic dolerite with resemblances to an augite andesite. Owing to its volcanic origin the latter name is preferable.

Greenstones.—The majority of the volcanic rocks are fine-grained greenstones. They vary in composition from fine-grained amphibolites to dolerites and amphibolite schists. Most of the fine-

grained rocks are of the fibrous amphibolite type which ar
abundant around Kalgoorlie. There are also coarser varieties
as gabbros and epidiorites, which are probably local variation

Fig 7.

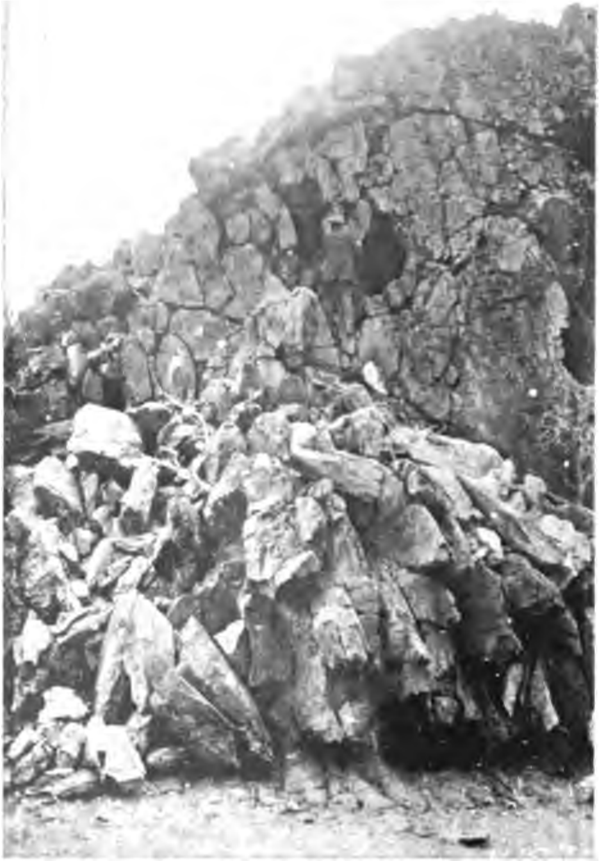


Photo.: C. S. Honman. Neg. 1497.

Pillow structure east of Yerilla, on Lake Raeside.

the fine-grained greenstones, because, in most cases, no defi
boundaries can be made out between the coarse-grained rock a

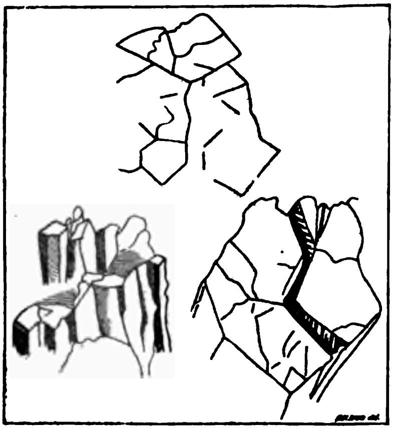
the fine-grained ones. An exception occurs at Eucalyptus, where a coarse-grained gabbroid rock with sharp boundaries intrudes the greenstone schists.

At times, the fine-grained amphibolites have a development of porphyritic felspars in them, and when weathered resemble the markings on a native cat, hence in other districts, such as Ora Banda, they have received the local name of "Native Cat" rock, which is convenient as a distinction from the uniformly fine-grained greenstones.

Most of the greenstones are schistose, and even when to all appearance massive, have an incipient schistosity developed.

They are a most interesting series, and have many of their lava flow characteristics preserved, though the wonder is that after subjection to the great pressures to which they have been liable, that they have any such characteristics left. The most prominent and best preserved structure is the vesicular or amygdaloidal. Almost all the greenstones are amygdaloidal at some part or another, and they might conveniently be termed "amygdaloids." This structure is very noticeable at Linden about three-quarters of a mile southeast of the Government Tank; at Yundamindera, east of the townsite; near the 17-mile peg on the Yundamindera-Linden Road (Fig. 5); and is represented in all parts of the greenstone area. The best occurrence is along the western shore of Lake Raeside from a point opposite Yerilla northwards to the limit of the map. Besides the

Fig. 8.



Columnar structure near R. 67 on Lake Raeside.

amygdaloidal structure, beds of volcanic breccia occur here, structures, such as shrinkage cracking, “pillow” structure and “or pipe” or “columnar” structure. (See Figs 6, 7, and 8.)

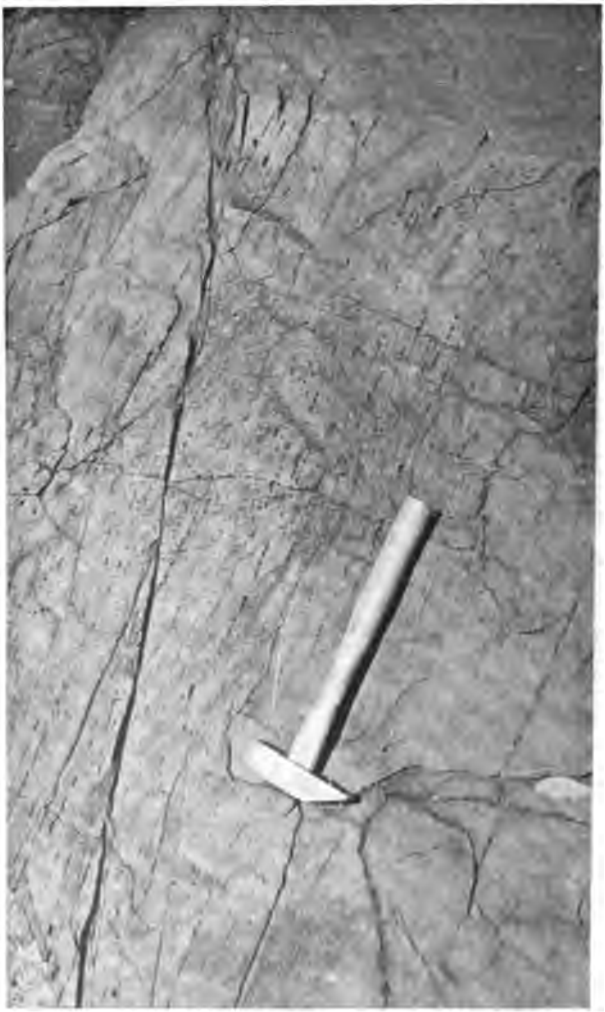


Fig. 9.

Neg. 1294.

Photo.: C. S. Honman.

Vesicular structure in Greenstone on Lake

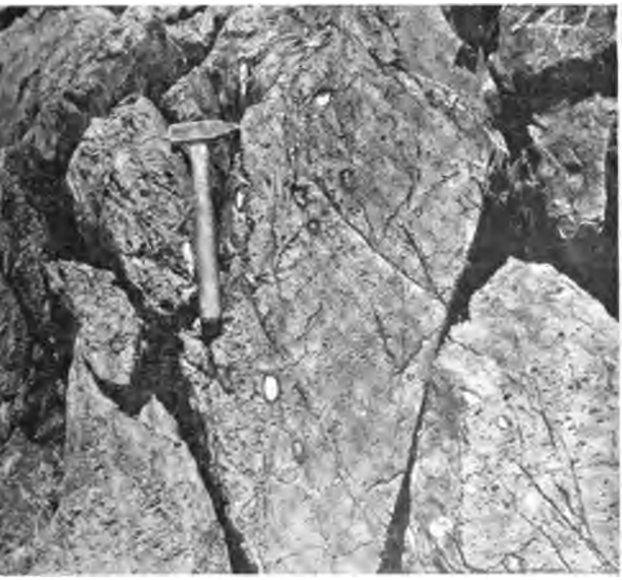
Mr. Maitland referred to these rocks in 1903, and suggested their possible volcanic origin.

In 1914 Mr. Jutson, while examining the Yerilla centre, noticed the amygdaloidal structure on an island three miles north of B 75.

rticular island the amygdules are particularly fine and
pea-size up to hen-egg size, and even larger. They are
f an inner kernel of quartz with an outer shell of iron-
onate. They are mostly almond-shaped, due to elonga-
shing. (Fig. 10.)

of the island and along the cliffs on Lake Raeside, some
ections showing the various structures of the schists can
hrinkage cracks are very common in certain bands of

Fig. 10.



T. Jutson. Neg. 1241.

ygdaloidal structure on island east of Yerilla.

ig. 6). Agglomerates or breccias occur interbedded with
s which are vesicular near their surface (*see* Fig. 11).
structure is very common. (See Fig. 7.)

ight miles west of Mt. Kildare there is a range of green-
hich show some good volcanic structures. A "columnar"
ipe" structure distorted, but distinctly recognisable, is
he cliff face bordering the lake (see Fig. 8). The "Cat-
o represented, at this place apparently resting on the
bed, which is dipping 30° north-east. Between the
d and the "cat-rock" there is a narrow bed of rhyolite.
est of Yerilla there is a breccia which might have been
he crushing of a flow which was riddled with shrinkage

cracks, since all the fragments are composed of similar materi
very angular, and apparently fit into each other like a mosaic
the other hand, it may be a volcanic agglomerate of which the
some undoubted representatives in the series. (Fig. 12.)

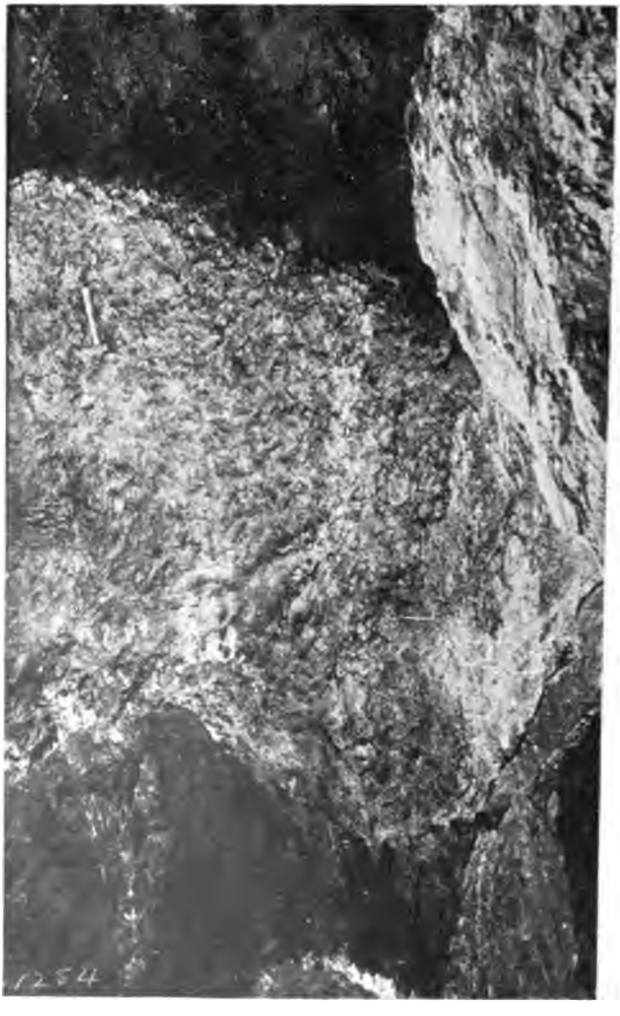


Fig. 11.

Photo.: C. S. Honman.

The amygdaloids and shrinkage cracks are generally filled w
carbonate which, in many instances, has been leached out where
rock is exposed to atmospheric weathering. (Fig. 13.)

esting rock occurs at Yundamindera, just beyond the
It is surrounded by granite, pear-shaped, and about

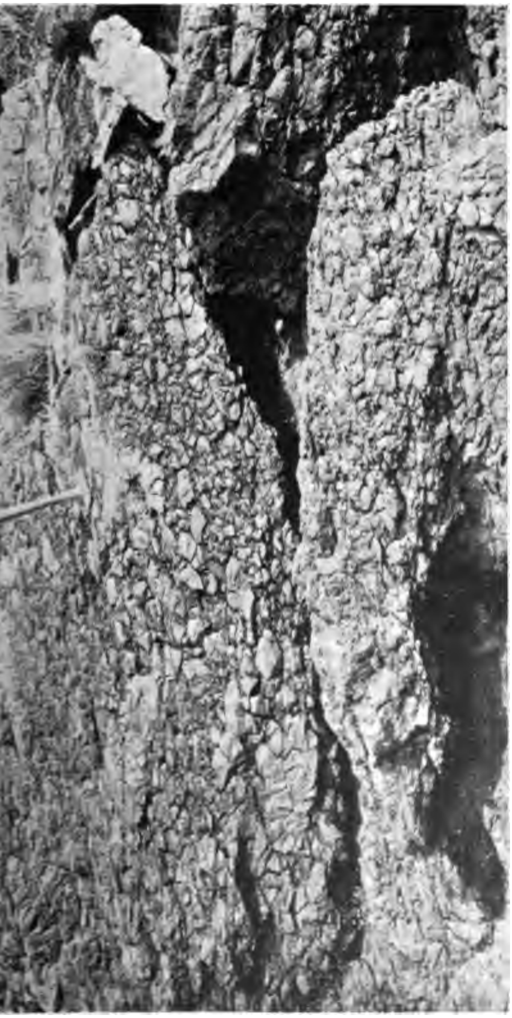


Photo.: C. S. Honman. Neg. 1291.

Supposed Agglomerate in Greenstones on Lake Raeside, east of Yerilla.

5 chains. Mr. Farquharson describes it as an augite
ffinities to a camptonite. It is probable that it is a
, from which the flows from the greenstones were de-
ed.

NEWER SEDIMENTS.

Conglomerate Series.—An extensive development of ates, arkoses and tuffs occur at Yilgangi, which is repres a continuous belt of sedimentary rocks which outcrop f miles in length.

The belt is from two to three miles wide. It extends far south as Mulgabbie, where outcrops occur about three of that centre. Between Mulgabbie and Yilgangi they ca at many points, undoubtedly from a continuous belt.

There are two main bands of conglomerates about apart, one band passing east of Mt. Ruth and one throu mile post on the Yarri road. They are interbedded with ar and flows. Some intrusive porphyry dykes occur in them, sheared porphyry which was probably originally a seri sills or flows. The intrusive porphyry has large crystals developed in it. (Fig. 13a.)

Some of the conglomerate bands south of Yilgan greenstone fragments and approach coarse volcanic agglo places.

The porphyries at Yilgangi contain quartz reefs w some rich patches of ore. The geological conditions at Y exactly similar to those at Binduli, four miles west of Ka

A report on Yilgangi by Mr. J. T. Jutson, is attac report as an appendix (i.). In it the petrology is fully and the rocks are more fully described.

At the 11 mile-post on the Yundamindera-Linden r glomerate bed occurs which is probably contemporaneou Yilgangi series.

The Yilgangi series is probably younger than the and were laid down during a period of volcanic quiescenc sequently folded into their present position.

INTRUSIVE.

Gabbros and Epidiorites.—The epidiorites are exte veloped in the northern portion of the district, but not s the south. A fairly prominent belt goes through Pyke' Eucalyptus, and Mt. Millbank.

Pyke's Hill is a typical outcrop of epidiorite rock. lyptus a gabbroid type occurs. The epidiorites are fo gabbros and dolerites by regional metamorphism, and are due to extreme metamorphism of the greenstone volcanic

The epidiorites are also very well developed at Mt.

A gabbro occurs at Mt. Boyce, on Yerilla-Edjudina r was apparently formed by recrystallization of a boss of fi greenstone, having no definite walls but merging into fi greenstone.

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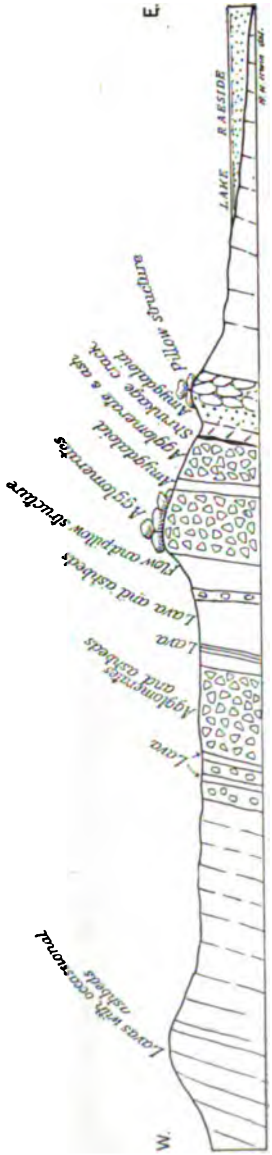
[1] Bulletin 56, G.S., W.A.

ites and Derivatives.—These rocks, which are very com-
district, are recognised by their black colour when fresh,

Fig. 13.



Diagrammatic Section in Greenstones on Lake Raeside, east of Yerilla.

inous appearance when altered. They have always as-
h them actinolite asbestos and common opal, which, con-

sequently, are an infallible indication of the presence of serper rocks.

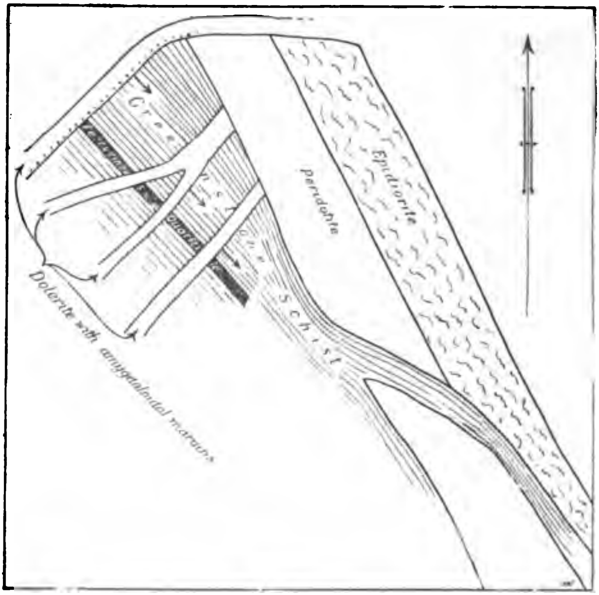
They occur mostly as serpentines and dolomites in parallel which are parallel to the ferruginous quartzites and greenston

There are two principal belts:—

(1) Passing through Pyke's Hollow, east of Eucalyptus, of Mt. Millbank, and southwards as a ridge of west of Mt. Millicent, on west side of Lake Raesic

(2) Passing through Greenhills, Linden, and west of Celia.

Fig. 14.



Showing relation between Schists and Peridotite, north of Linden.

A dolomite phase of this rock occurs south-east of Edju and about three miles east of Stephani's Well; this is probab continuation of the second belt, and the dolomitisation is prob due to cross fissuring which occurs in this vicinity.

Belt No. 1 is at the same distance west of the Edjudina Millicent quartzites as No. 2 is to the east and both are paralle the ferruginous quartzites which forms an anticlinal ridge. peridotites have, therefore, probably intruded along the east

f an anticline. Their equidistance from the quartzite
e intrusion taking place along the same horizon in the
series.

Neg. 1397.

Photo.: C. S. Honman.

Porphyritic Granite near Calvalley Soak.

are other minor occurrences of serpentine rock, one in
on the western fall of Mt. Howe.

west of the Bore Well, on the Linden-Edjudina road,
rominent range of talc schist which is probably a foliated
f the peridotite belt.

nden there is a very important section showing the rela-
n the greenstone schist, ferruginous quartzite, serpentine
rite, which although occurring as a dyke has an amygda-
gin. (See Fig. 14.)

Granite, Granodiorite and Syenite.—These are appar younger than the greenstone rocks of the district. There are (3) distinct belts, the two outside ones being distinctly diff from the centre one.

The central belt, which is probably the youngest, extends Yundamindera to Mt. Kildare and south-south-eastwards in a regular manner past Mt. Percy to Yarri, and connects to the granite batholith north-east of Mulgabbie and of which the out at Calvally Soak are typical.

The central granite varies greatly in composition, and is acterised in its central or more massive portions by an abun growth of felspar crystals which are as large as two to three i long at times, and might be called a medium-grained biotite gr with large phenocrysts of felspar scattered through it. (Fig.

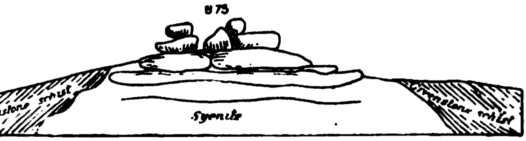
Close to its contact with the greenstone the granite bec more basic in composition, and at times with the complete ab of quartz thus forming a syenite or hornblende granite. Most o more basic granite would be most correctly termed granodi judging from hand specimens.

In many places along the contact fragments of greenstone be seen in the granite, apparently caught up as it intruded the la This is very noticeable near Yarri and south of Mt. Percy. At damindera the granite has changed to a granodiorite in proxi to the greenstone contact, and there are many patches in the gra there which are apparently due to basic differentiation, due to sorption of basic material by a granite magma. The basic diffe tiations only occur close to and at the contact of granite and gr stone. Typical specimens of the marginal hornblende granite M.S. [$\frac{1}{903}$] at Yundamindera, and M.S. [$\frac{1}{367}$] and [$\frac{1}{368}$] betv Edjudina and Pingin.

Many tongues from the granite batholith seem to merge sheared porphyrite as they narrow and tail into the greenstone se This supports an origin of some granite from certain acid rocks curring in the greenstone series (probably acid sills or flows) absorption, and overhead stoping from below.

A very good example of the syenite type of granite occur Soak B. 75, east of Yerilla. This has been described by Mr. Ju as syenite, and is apparently an outlier of the central granite m The syenite is surrounded by greenstone and covers an area of a two square miles. It may have some connection with a belt of shea porphyry or porphyrite which outcrops near it and extends to northwards as far as Mt. Remarkable. It may have been forme the absorption of this porphyry belt. Near the soak the syenit horizontally sheared which may be due to the outcrop being the of a dome, the greenstone lid of which has been denuded away l erlying syenite granite exposed. (See Fig. 16.) The eavage was probably parallel to the contact of the green-emoved.

Fig. 16.



h showing horizontal laminations in Syenite at B 75.

ier belts of granite occur east and west of the central belt.

The western belt of which Menangina Rock is the central portion.

The eastern belt through Kirgilla Rock and Dead Horse Soak.

ese belts are composed of ordinary medium-grained bio-

e belts the patches of gneiss occur, which I have des-, as Archæozoic remnants of old basements on which the were poured out.

ry.—Intrusive into the greenstones there are numerous kes. These are especially numerous at Linden, and also distributed throughout the district, especially near the acts. These dykes are probably apophyses from the tes. This is very clearly demonstrated near Mt. Wall- an arm of the newer granite can be seen intruding chists and sheared porphyry, and gradually changing rphyry. A similar change is also noticeable at Linden, tcher's Well.

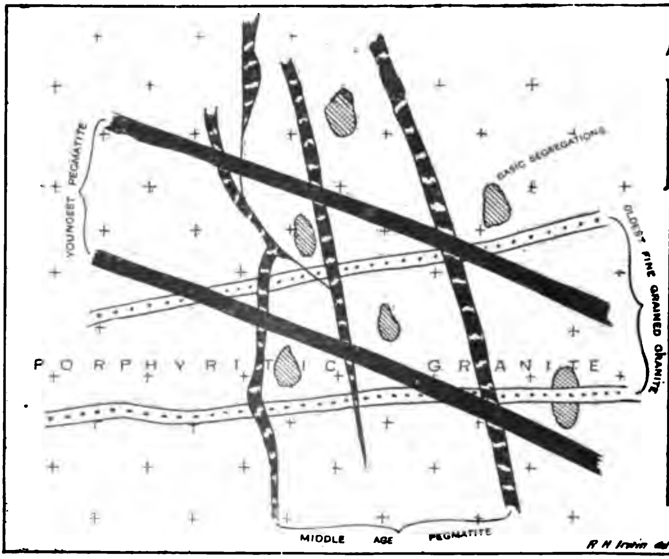
te Dykes.—These are the youngest intrusives in the dis-n be seen extensively intruding both the main granite greenstones. This is very noticeable on a flat rock five f Pingin. Here three ages of pegmatite veins can be coarse porphyrite granite. (See Fig. 17.) The oldest granite dykes are east and west, the middle-aged peg-n-north-west and the youngest pegmatite west-north-

a great deal of intrusion by pegmatite dykes at Yun-which has taken place subsequently to the formation of eefs. This is very noticeable in the Queen of the May

Mine, and in some workings at the south end of the Queen of
May line (see Fig. 18).

Dolerite.—This is a black, fine to medium-grained rock, w
is the latest intrusion in the district. It is undoubtedly later
the fine-grained greenstones, which it can be seen intruding, o
island on Lake Raeside, east of Yerilla (see Fig. 19), and obse
by Mr. Maitland in 1903. A dyke of the same rock intruded
granite about five miles south of Yarri. This can be seen on
dump of a well which was sunk on the hanging wall side of the
and from which a shallow supply of good water was obtained.

Fig. 17.



Showing dykes in Granite at Pingin Rock Hole.

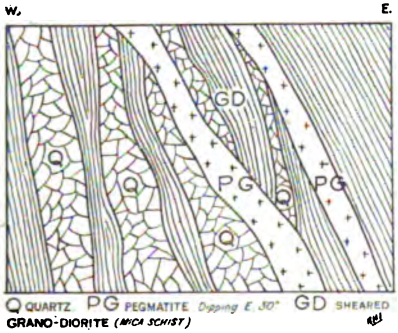
Mr. Montgomery also describes xenoliths of granite in dole
occurring on the granite dump of the Yarri Well. This is prob
from a dolerite dyke in granite in which the Yarri Well is s
The granite xenolith proves the younger age of the dolerite.

No direct evidence was observed as to whether the dolerit
younger than the pegmatite dykes, but in other districts this
been proved to be the case, and it is more than probable that
dolerites are youngest in the Yerilla district.

Deep Alluvium.—There are undoubted indications of the
sence of extensive deep alluvial ground in the district. Especi
is this the case in the country south-westwards of the Yundamind
Linden higher land belt. There is a belt of ground between

d and Lake Raeside which varies from seven to three miles
nd over the whole of which it is possible that deep alluvial
even of the wells sunk in this area are in alluvial ground,
ve good drinking water.

Fig. 18.


W.
E.
GD
PG
PG
Q
Q
Q
Q
Q QUARTZ PG PEGMATITE Dipping E 30° GD SHEARED
GRANO-DIORITE (MICA SCHIST)

Sketch of section in workings, south of the Little Wonder G.M., Yundamindera, looking north.

tzites.—A number of hills in the district are capped with
rizontal quartzites and conglomerates, viz.:—

Mt. Colindina, or "The Table Top."
is a fine landmark and can be seen for miles from the

Hill at 17 mile post, Yundamindera-Linden Road.
Hill two and a half miles south-west of Edjudina new
townsite. Synclinal formation on this.
Hills around Mt. Celia.

same material occurs as scabs all over the country as
ey were remnants of an, at one time, extensive formation.
Deep Alluvium and the Quartzites are probably of the
and may be correlated with the Kanowna deep alluvium
the deep leads occur.

undamindera there are two shafts down 40 feet to 50 feet
round with a good bottom (Fig. 20).

ucalyptus there are indications of deep ground, and also
lia, where large rounded pebbles occur west of the Trig.

my opinion that there is considerably more deep ground
trict than appears on examination of the surface, owing to
sive cappings of cement which seem indiscriminately to
omposed country rock and alluvium (see Fig. 21).

The *Recent deposits* of shallow alluvium, aeolian deposits and cements and laterites are similar to those extensively occurring throughout the eastern goldfields and have been described in other publications of the Geological Survey, so that no further reference is necessary here.

HISTORICAL GEOLOGY.

A brief outline of the geological events leading to the present structure of the district is as follows:—

First, there was a gneissic basement upon which volcanic action has caused the spreading out of numerous lava flows, mostly of basic composition. During periods of quiescence the sedimentary beds now represented by ferruginous quartzites, were deposited. Then further lava flows, including in subordinate amount rhyolites and porphyrites. Then quiescence and denudation with formation of arkoses and conglomerates. This is followed by folding, during which period the gneiss becomes intruded and absorbed by granite. As the folding proceeds, due to tremendous pressures from east and

Fig. 19.

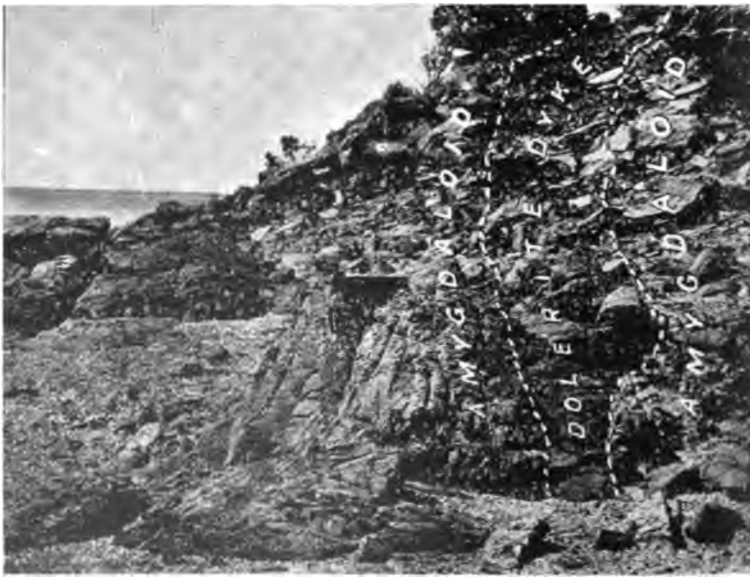


Photo. : J. T. Jutson. Neg. 124

Dolerite dyke in Greenstone on island on Lake Raeside, east of Yerilla.

ore and more gneiss is absorbed by granite, and granite in-
avas, which are now tilted and warped into elongated areas
led by granite. Finally, general regional metamorphism

Photo.: C. S. Honman. **Dump of Alluvial material, Yundamindera.** Neg. 1498.

ace, fracturing faulting, squeezing, shearing, etc., and the
structure results. Denudation forms rivers, lakes, etc., and
changes in climate and in sub-arid conditions and the for-
of dry lakes, cements, alluvial and aeolian deposits.

STRUCTURAL GEOLOGY.

Many interesting structural problems have been brought out b
the mapping. Among the more important are the following:—

(1) Extensive foliation of older rocks.

Fig. 21.

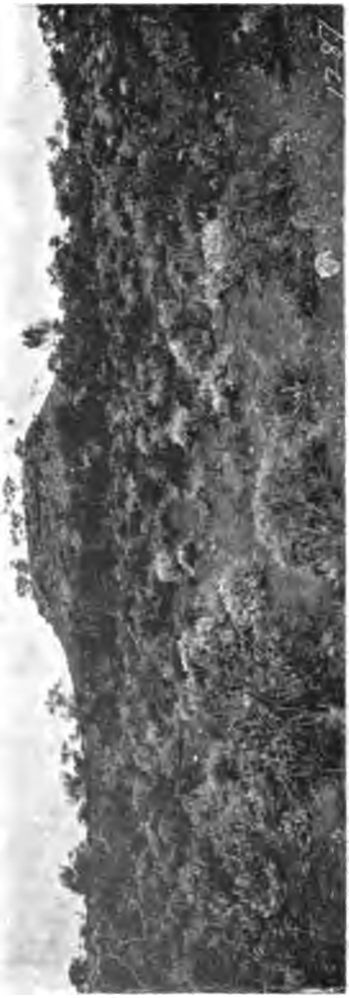


Photo.: C. S. Honman. Neg. 1287.

Quartzite capping at 17 M.P., Yundamindera-Linden Road.

(2) Big folds in the older rocks. These are masked to great
extent by foliation, but mapping shows that certain types

rocks cover large areas and apparently belong to individual folds. It is probable that the folding is not as steep appears owing to the masking effect of foliation.

Fig. 22.

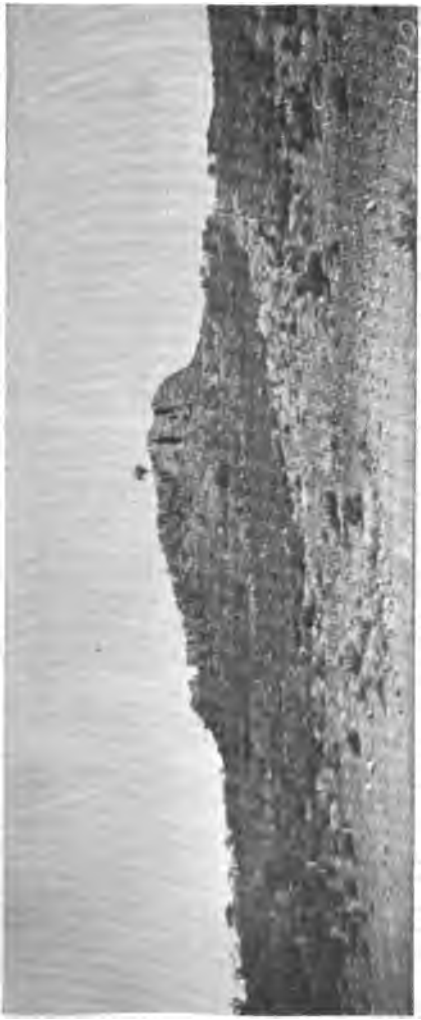


Photo.: C. S. Honman. Neg. 1290.

Ferruginous Quartzite ridge on Yundamindera-Linden Road, looking south.

There are two distinct folds:

(a) Anticline, whose axis is represented by the Edjudina-Mt. Millicent ferruginous quartzites.

(b) Synclinal formations whose axis passes som
where through Yilgangi and in which th
conglomerates and Lake Raeside volcani
occur.

(3) Two very prominent fault or thrust planes striking near
north-west and parallel.

(a) The Mt. Celia-Yundamindera fault.

(b) The Edjudina-Yerilla fault.

It is very significant that all the important gol
discoveries have taken place in the vicinity of eith
of these fault lines.

(4) All the greenstone schists and quartzites show signs
corrugation. Such corrugations always pitch north
about 20° (Figs. 22 and 23).

MINING GEOLOGY.

Mining in the Yerilla District has never had a solid footin The deepest workings are 400 feet, and very little ore has been take out below 200 feet.

Most of the mines, or rather prospects, in the districts are no deeper than water level.

At the time of this survey Linden was by far the most im portant centre, with a population of about 70. Next comes Edju dina, Yarri, Yerilla, Yundamindera, and Pingin. Eucalyptus Pennyweight Point, and Pyke's Hollow were deserted.

Yundamindera has produced more gold than all the rest pu together. This was owing to the operations of the Mt. Margare Reward Claim Co., which had taken over the Potosi, the Queen o the May, and the Treasure Mines.

The Yerilla centre has been reported on by Mr. Jutson as lat as 1914,[1] and there is no need to further discuss this centre, as n fresh developments have occurred since Mr. Jutson's visit.

The Mining centres are dealt with in the following order:—

Yundamindera.
Pennyweight Point.
Eucalyptus.
Pyke's Hollow.
Old Joe's Soak.
Linden.
Mt. Celia.
Mt. Howe.
Yarri, Edjudina, and Pingin.
Mt. Remarkable.

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[1] Miscellaneous Reports 53, Bulletin 64, G.S.W.A.

YUNDAMINDERA.

necessary to give an outline of the geology as the gen-
on of the district applies to the Yundamindera centre,
eological map accompanies this report.

Photo.: C. S. Honman. Neg. 1288.

Ferruginous Quartzite ridge on Yundamindera-Linden Road, end view, looking south.

mine working in the centre is the Queen of the May,
e described first.

the May, G.M.L. 466. (Plate IV.).—The owners are
on a quartz reef which strikes 10° west

of north and has been worked to a depth of 140 f
The reef is, as seen in North drive from bottom
shaft, a continuous body of quartz which thins out to a f
inches in places, but should average 12 inches as there
bulges which make up for the narrow parts. At 280 feet north
the shaft the reef adjoins a large formation (6 feet) which
composed of quartz and granitic schist. This is apparently fr
where the reef from the old workings in the south end of the lea
which strikes 25° west of north, joins the new reef as it should
if produced to cut the new reef. The north workings are aba
doned. They were worked by a company which operated a numb
of leases at this centre in 1904, or thereabouts. In the old no
workings, according to the mine plans, there is a shoot stoped f
a length of 370 feet. About 180 feet north of the present ma
shaft there are old workings which are shown on the plan to ha
a shoot of gold over 100 feet long. The shoot of gold at prese
being worked is about 150 feet long, and at the junction of the
and new reefs a new shoot has been driven on for about 70 feet.

This mine is practically in its infancy, for according to t
mine plans very little has been taken out below water level, a
there is every indication that the reef will live in depth and mai
tain its values for at least 400 feet and over. The structure is su
as should be persistent and regular, and there are no rocks in t
proximity that would cut it off. There are, however, a number
flat granitic and pegmatite dykes which will cut through the re
but these will not cut it off. In the Queen of the May North lea
a good deal of work has been done to pick up the reef, but so f
without success, although the boundaries have been thoroughly pro
pected. A narrow vein has been cut about the line of strike of t
new reef, and this is probably the course of the reef and should
worth opening out on if no other indications are come across.
the North lease is a big blow of pegmatite which will probably i
terfere with the reef in that lease.

The gold production from the Queen of the May, according
official statistics, is 2,340.73 fine ounces of gold from 2,426.60 to
of ore, or nearly 1oz. per ton. This does not include the recove
of the Mt. Margaret Reward Claim Co., which has bulked its r
turns from Yundamindera, so that their figures give no indicati
of what they extracted from the Queen of the May.

An interesting mineralogical occurrence in this mine is th
presence of Electrum, an alloy, and silver and gold. This was e
pecially plentiful at the junction of the new reef and the old reef

The other mines of the district have been closed down for yea
in spite of the fine record of 47,432.17 fine ounces of gold extract
from 68,628.60 tons of ore (2,240lbs.). The Treasure Leases, t
Potosi Consolidated, and the Queen of the May were held by t
Mt. Margaret Reward Claim Co.

Potosi Consolidated, G.M.L. 450, is situated about one mile he Queen of the May. The reef strikes 60° west of north to the east. There is an incline shaft down to 400 feet, ull of water up to within 90 feet of the surface. Accord- mine plans not much work has been done below 200 feet, to that depth a shoot of ore has been taken out which has e length of 200 feet. The reef, according to the assay e company, is consistent in size, varying from one foot to in width (Plate V.).

ountry rock is a grano-diorite which is changed to a gran- on the walls of the reef. There are apparently basic ns in the granodiorite judging from the dump.

Treasure and the Treasure South are leases on which a le amount of work has been done and from which some stone has been taken. The main reef in this mine, which to some extent, has an average strike of 30° west of north to the east at varying angles along its strike, viz., from °. The average strike appears to be about 60°.

mber of branch reefs occur, one striking east and west and 0° north. Another about 20° west of north.

t 200 feet from the south boundary the main reef has ed and the shoots apparently occur on either side of this

itch of this twist in the reef is to the north-east and should at depth north of the new shaft which has been sunk at a feet east of the outcrop, to a depth of 300 feet. From al dip of the reef at the surface I should think that this ld require to be sunk to a greater depth to cut the main posing the main reef dipped at 60° indefinitely, then the ld have to reach 700 feet to cut it. It is unlikely that the retain a uniform dip, but it would have to turn very flat shaft at 300 feet. According to the mine plans the cross- 7 feet level is not far enough west to prove whether the t 303 feet in the shaft is the main reef or not. I think it well worth while to extend the cross-cut at 287 feet, pro- ad not been already done: and if no further development drive further north on the reef that has been cut. Ac- the mine plans, at the 200 feet level there is one shoot of ly 400 feet long.

mine, like the Queen of the May and Potosi, is in grano- th granitic schist walls on the reef, and is not far from stone contact (Plate VI.).

are a number of other abandoned shows at Yundamindera e well-defined reefs, and should deserve further prospect-

The Maori Queen, G.M.L. 541, has produced 1,569.26 fine o from 1,063 tons. This must have been obtained from bulges, as fr an inspection of the old workings, only a narrow trace of quartz be seen for hundreds of feet.

Of the other abandoned mines the most promising is the Qu of the May South, G.M.L. 467, which has produced 1,211 ozs. fr 694 tons. From an examination of the old workings there appears be a long shoot of gold on this reef which has not been worked any depth. The reef occurs in a well defined fissure which is the c tinuation of the Queen of the May south reef, and should live t great depth. It was probably only worked to a shallow depth account of its occurring so close to and dipping into the adjoin lease (the Pindinnie Deeps).

In the *Little Wonder,* G.M.L. 522, there are some big bodies quartz, but the gold either occurs as patches or only on one wall the reefs, judging by the amount of work done and the returns 1,333 fine ozs. from 449 tons of ore.

PENNYWEIGHT POINT.

This centre is three miles east of Yundamindera and occurs greenstone country, but not far from the granite contact.

About one mile west of Pennyweight Point (G.M.L. 3468), l 688R, known as the Just in Time, is a fair sized quartz reef r ning east and west, dipping north and crossing the granite cont almost at right angles. The returns show 396 fine ozs. from tons of ore. This is probably from a narrow shoot of gold occurr in the reef near the contact of granite and greenstone.

A similar occurrence is the Washington, G.M.L. 3273. This also an east and west reef crossing the contact. The returns to 649ozs. from 923 tons.

This show is situated one mile north of Pennyweight Point

The A.W.A., G.M.L. 562, has produced the most gold from t centre, viz., 1,190ozs. from 620 tons

The Highland Chief, G.M.L. 568, north of the A.W.A., has p duced 58ozs. from 58 tons. The Battleville Battery has also crush a good deal of stone from this lease.

The A.W.A., the Highland Chief, and the Tucker Bag all ha the same geological structure, viz., narrow shoots and patches in east and west reef cut by north-north-east and south-south-w porphyry dykes.

In G.M.L. 330 another porphyry dyke runs north-north-w and some rich alluvial claims were worked below it. The alluvial probably from a cross reef cut by the dyke.

There are a number of shows between Mt. Keith and Yund mindera which belong to the same class of deposit as the Tuck

Bag and the A.W.A., viz., east and west quartz reefs cutting porphyry dykes (at the Highland Chief the porphyry appears to cut the reef) short shoots and patches close to the intersection of porphyry dyke and reef. Many of the alluvial patches have been shed from this class of deposit. The latest rush to "the Patch" south of Porky's Leader, is an instance. By following up these intersections new patches of alluvial should be found.

EUCALYPTUS.

An extensive deposit of alluvial gold occurs here, which has been shed from a series of south-east and north-west reefs arranged "en echelon" in the bend of a horseshoe-shaped intrusion of gabbro.

The alluvial has spread out on either side of the outcrops which have been worked for rich patches of stone. Outside the horseshoe-shaped gabbro some auriferous reefs occur, but they are generally close to the contact. The country rock is greenstone schist.

At Brown Hill, about a quarter of a mile south, a reef striking north-north-west and dipping east, has shed some alluvials and contained some rich patches of stone.

No record has been kept of the amount of alluvial gold won from Eucalyptus, but it must be over 2,000ozs. according to report.

PYKE'S HOLLOW.

This centre is four miles north of Eucalyptus.

A number of shows have been worked here. The majority have the same geological structure, viz., short shoots of gold and patches occurring in quartz reefs at their intersections, with bands of slates in greenstone country rock. The reefs generally strike north-east and the slates north-north-east.

This centre is completely deserted. The principal shows were:—

The Yando, G.M.L. 504.—From an inspection of the old workings it seemed evident that the rich patches occurred at the intersection of a band of slates striking 24deg. east of north, and the schistose hanging wall of a basic dyke striking 355deg. In the basic dyke there occur shrinkage cracks which are filled with blue quartz and run across the dyke. In the schists and slates there are vertical white quartz leaders. The gold apparently occurs in white quartz, judging from the paddocks. The quartz is fractured and seamed with iron oxide.

Statistics show that 2,802.21 fine ozs. of gold were obtained from 74 tons of ore. This shows that there is very little battery stone and that the gold occurred as rich patches, probably along the line of intersection of slates and schists as described above.

The Nine of Hearts, G.M.L. 959 (late 803R).—The main shaft now used as a Government well.

The Hands across the Bar, G.M.L. 898, and *The Triumph*, the same geological structure, viz., a large quartz reef crossi band of slates, but in the case of the Triumph the quartz reef with the slates. The quartz as a whole appears to be barren an gold occurs as patches on either wall of the lode. The slates are at the surface but are probably graphitic at depth.

The Harlech Castle, G.M.L. 563R, was a very rich show. gold occurred as rich patches where a number of irregular le cut a band of ferruginous slates. The leaders extend across band of slates like the legs of a caterpillar. The returns show only seven tons of stone were treated for a yield of 1,119ozs., of which was dollied and specimens. This show has been work water level. All the other shows of this centre are associated the slate bands. The only exception noticed was Wilson's clai few chains east of G.M.L. 3461, on which there is a quartz striking north-north-west along the contact of talc schist and phyry, probably a porphyry dyke.

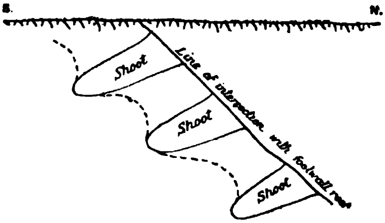
OLD JOE'S SOAK.

About a mile south-east of Old Joe's Soak a show know the St. Patrick has been worked. It occurs in greenstone s five miles north of the granite contact and is roughly on the tinuation of the Yundamindera line of leases. Some rich stone taken out, 19½ tons yielding 65 ozs. of gold. I have been infor that the reef cut out. The reef strikes nearly east and west dips 50° north.

LINDEN.

There was a great deal of activity at this centre. A nu of options had been taken over some of the more important sh viz.: The Olympic, The Devon, and the Lady Ethel.

Fig. 24.



Hypothetical Longitudinal Section Olympic Lode, Linden.

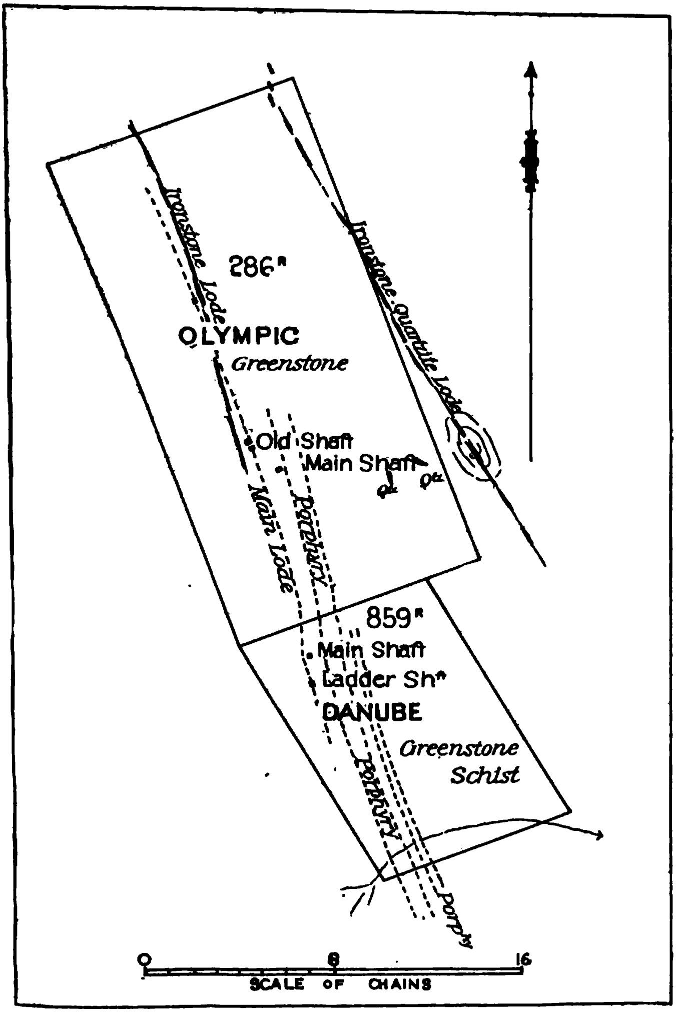
The geological structure is graphically represented on the companying geological map of the centre.

The main country rock is greenstone intruded by peridotite and, later, intruded by granite and porphyry.

The mines in this centre are:—

The Olympic and the Danube, G.M. Leases 286R and 859R respectively.

Fig. 25.



Sketch Plan of Olympic and Danube Leases.

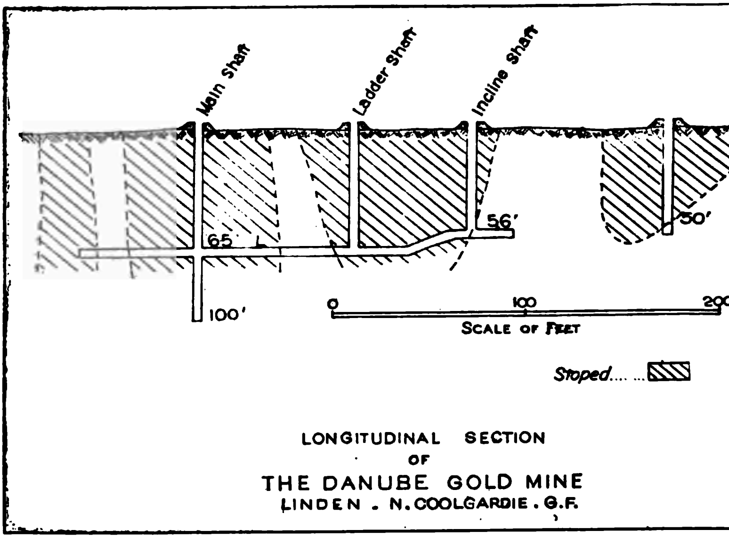
These mines are on the same line of lode, which consists of a shear zone in fine-grained greenstone about three feet wide and

dipping east at between 70° and 75°. In this shear zone a
reef occurs which varies in width from a few inches up to tw
at the widest part. The gold occurs in the quartz and forms a
about 35 feet long which appears to be pitching south at abou
There is a quartz reef coming in on the footwall whose inters
with the lode pitches north at about 45°. One would expe
shoot to keep parallel with this intersection, since at the 6
level the shoot is alongside the intersection. It is, however, pr
that there is a series of parallel shoots pitching north, each st
from the line of intersection, but each shoot some distance
the other, as in Fig. 24.

The real pitch of the series would, therefore, be north.

The Danube, G.M.L. 859R.—This lease adjoins the Olympi
is on the same line of lode. At first sight it looks to be in
ferent class of country, but closer inspection shows that the
pic country is merely an oxidised zone in the Danube count

Fig. 26.



Longitudinal Section of Danube Lode, Linden.

The lode is the same as that in the Olympic except that
it occurs in unoxidised country the walls are better defined.
shoots of ore occur in the lode in a distance of 370 feet on the
face (Fig. 26). The longest shoot is 100 feet on the surface bu
shortened to 65 feet at a depth of 60 feet, and probably cut

. I have been informed that this shoot averaged six inches and crushed at the rate of 2½ ozs. per ton.

h of this shoot there are two more shoots which are vertical, same length at 65 feet as at the surface, viz., 75 feet and The 75 feet shoot averaged six inches wide and crushed per ton.

26 feet shoot was narrow but averaged 4 ozs. per ton.

south shoot cut out just below 50 feet and was poor.

greatest width of stone is 18 inches, and there is generally seam on either wall of the schistose zone. The lode dips °, and runs parallel to a porphyry dyke which, close to the ft of the Olympic, has a slight dip to west. This porphyry l probably cut through the lode, but will not cut if off. . 25.)

Devon, G.M.L. 903R.—The mine occurs in a medium to ained dolerite which is changed to epidiorite in places. lode consists of a shear zone in the greenstones which up to 12 inches wide. It strikes 30° west of north and west. A footwall lode cuts the main lode and comes in north, striking 20° west of north and dipping 55° west. lodes should meet on the surface very close to the south of G.M.L. 903R as their line of intersection pitches at 35° rth, and at the 50 feet level the footwall lode is about 10 of the main lode at a point 36 feet north of the main

best shoot of gold occurs in the main lode and south of is cut by the footwall reef, somewhere between the Main aft and the Dreadnought shaft. A block 350 feet long and feet to 50 feet deep has been stoped from between these ts. According to figures supplied, some very rich stone from this block.

north workings have not developed satisfactorily and the enerally small.

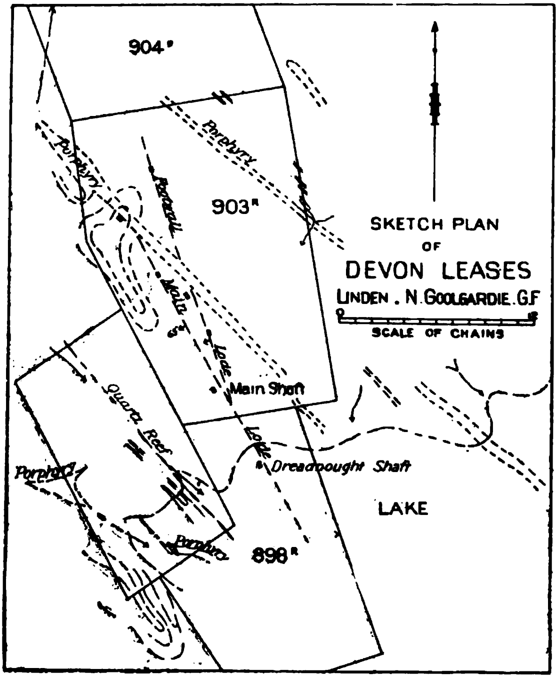
lopment work has been greatly handicapped in the south owing to the salty character of the water causing sores tion of the skin to anyone working in it.

workings south of the main shaft were inaccessible and no d be formed as to the size of the lode (Fig. 27).

Democrat, G.M.L. 871R.—This mine is the deepest at Lin- worked down to nearly 400 feet. The lode is an irregular ef in a contorted greenstone schist zone. In places the ries gold, but most of the gold comes from the quartz lead- and from the quartz reef.

lode strikes roughly 20° south of east and dips 75° north. y good ore has been taken from it. To the end of 1915, 1,960.25 tons of ore had been crushed for 4,354.18 fine ou Judging from the workings the shoot appears to be between 60 to 100 feet long and has been worked to a depth of 370 feet. provide a tonnage of 1,960 tons, 12 inches of lode would have crushed.

Fig. 27.



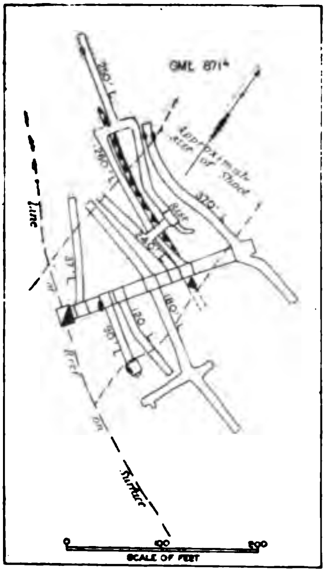
Sketch Plan of Devon Leases, Linden.

This is an extremely promising mine, and it is a great that it is not being developed. Very little cross-cutting has b done and practically no driving outside the shoot of gold. shoot of gold appears to be associated with a felsitic dyke, wh has been intruded along the lode in such a way that the reef occur on either side of the felsite. Sometimes kidney-shaped le of felsite are found isolated in the schist. The values are gener good when the quartz is close to the felsite. No water has b struck in this mine, and probably will never give any trouble. Th is any amount of room for prospecting and development of promising lease. (Fig. 28.)

The Great Junction, G.M.L. 942R.—Formerly known as Lady Ethel G.M.L. 387R.

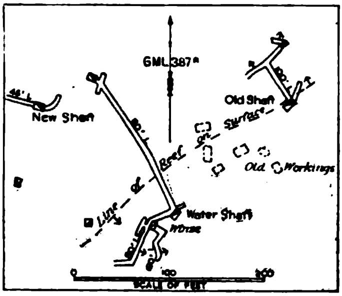
There are two reefs on this lease, both occur in a zone of contorted greenstone schist, which has been squeezed between two granite bosses to the north and south. The main reef has a general strike to the north-east across the schists, which strike to the north-west. The north reef is roughly parallel to the main reef,

Fig. 28.



Sketch Plan of Democrat workings, Linden.

Fig. 29.

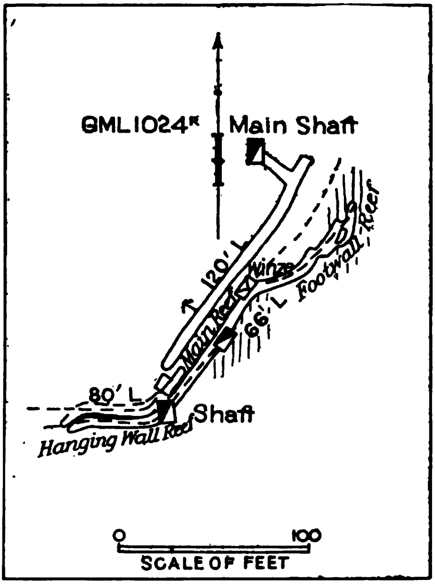


Sketch Plan of Great Junction (late Lady Ethel) workings, Linden.

but has not been worked to the same extent as the main reef. Both reefs have a very contorted course, sometimes following the planes of schistosity and sometimes across, and often squeezed into kidneys. The stone is very rich at times, but averages an per ton. 984 tons have been treated for 914 ozs. of gold.

The reefs are apparently cross fissures in a zone of grea tortion. Nothing definite can be said of their behaviour. north-east end of the main reef is dipping to the north-we has been worked to 100 feet, while the south-west end of th reef dips to the south-east, having apparently turned righ There is apparently no definite shoot, the gold occurring different bends, twists and in the kidneys in the line of reef. 29.)

Fig. 30.



Sketch Plan of Great Carbine workings, Linden.

The Great Carbine, G.M.L. 1024R (406R).—This mine c in a sheared porphyrite, which strikes practically north and s The ore body is a quartz reef, striking north-east and di north-west at 75 deg. A shoot of ore has been taken out fro surface to the 120 feet level, which is the deepest working i mine. The shoot seems to pitch to the north-east. Above the 6 level, the best stone came from close to the junction of a fo reef which junction pitches to the north-east. Below 66 fee footwall has been stoped, it joins the main reef and hence do the 120 feet level. The main reef north-east of the junctio been untouched below the 66 feet level.

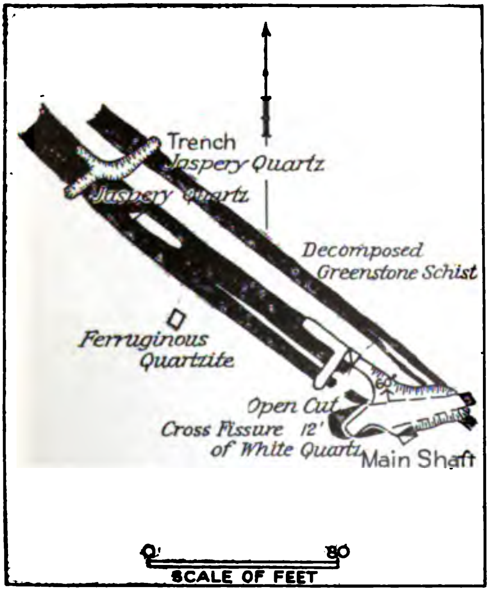
A hanging wall reef joins the main reef in the south workings, but this junction is practically vertical. A shoot o

occurs here. There is a fine body of quartz in places,
feet and more, but poorer than where the stone is small.
s from this mine show 1,117 fine ozs. from 1,721 tons of
30.)

indah, G.M.L. 998R.—This mine is situated seven miles
lightly south of east of Mt. Linden, and on the dry sur-
ke Carey.

how was abandoned at the time of my visit and full
From surface indications, it appeared to be a cross
ecomposed greenstone schist. The lode is a quartz reef
most east and west across a belt of schist, which is
rth-west and south-east. The reef dips to the north at
d appeared to have been 12 feet wide at the surface,
om the open cut. The shoot is about 50 feet long. A
artz formation runs parallel with the schists. The
been opened up by a number of costeens, but appar-
disappointing results. There is a large body of stone,
grade, judging by the results of crushings, viz.:—531
om 1,462 tons of ore. (Fig. 31.)

Fig. 31.



tch Plan of Bindah workings, 7½ miles east of Linden.

Greenhills, G.M.L. 408R.—This is an abandoned mine,
produced good results, viz.:—5,783 fine ozs. of gold from

3,198 tons. The workings are inaccessible, but I have been inf
that it has been worked to no great depth. The lode is in th
class of country as the Democrat and, judging by the geo
conditions, this mine cannot have been worked out. A
rock similar to that occurring in the Democrat can be seen
dump associated with the schist. The mine is situated cl
Lake Carey.

Fig. 32.

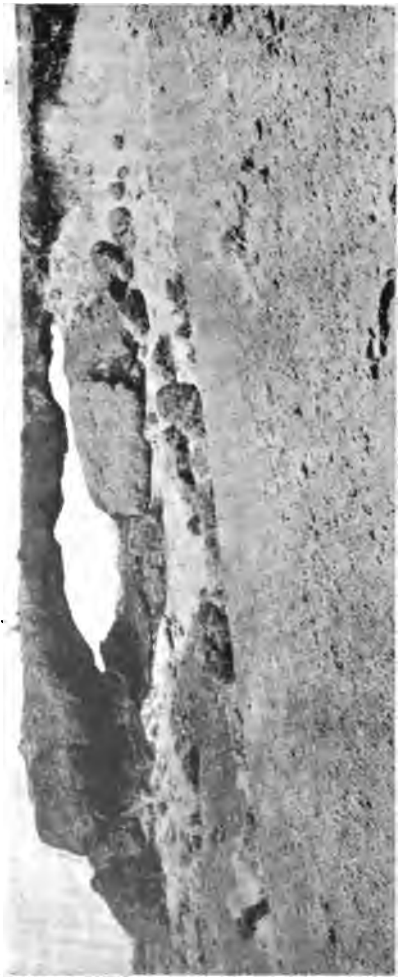


Photo.: C. S. Honman. Neg. 1285.

Breakaway near Bindah Gold Mine, 7½ miles east of Linden.

The Star, G.M.L. 881.—A narrow reef, striking north-eas
bending sharply to the south-east. The bend pitches steep

The north-east arm dips 60 deg. south-east; the reef
rd schistose greenstone, associated with felsite. It has
ozs. from 158 tons. The reef is too small and the
hard to make this a satisfactory proposition for even
ty.

ater Reserve Lease.—This is the latest development at
it has been opened up by an open cut with very en-
esults. It is to all appearance a "lode formation" of
lie type, and has several marked characteristics which
to such lode formations, viz.:—

walls. The width of the ore body can only be determined by
s. The lode is to all appearance similar to the surrounding
which is a fine-grained greenstone.
lode strikes across the foliation of the greenstone. .
best ore occurs close to " greasy heads " or " planes of parting,"
f such planes being present.
lode is impregnated with carbonate.

hing of 30 tons from open cut, over an average width
t, gave a return of one ounce per ton.

eenstones strike 13 deg. east of north and are cut by
ykes, striking 45 deg. east of north. The lode forma-
ntly lives through the porphyry and strikes between
d 80 deg. west of north, which is practically at right
reenstone. The lode will probably be impoverished in
y, as that is the general experience with such forma-

de is practically vertical and sulphides occur a little
surface, and there is, therefore, less likelihood of the
secondary enrichment giving enhanced surface pros-

en cut is situated about 25 chains north-east of the Gov-
k. There is a similar formation three and a half chains
of the main lode, but not much work has been done on

MT. CELIA.

ne prospector was at Mt. Celia in 1916, on a prospecting
mile west of Mt. Celia Trigonometrical Station. He was
a quartz reef in granite striking 287deg. and dipping
e north-east. There are some large quartz reefs in the
Mt. Celia, especially in the greenstone schist near the
tact. A number of them have been worked, the gold
occurring on one wall only.

untry around Mt. Celia is well worthy of further atten-
ally the long persistent quartz reefs in the greenstone
the granite contact.

MT. HOWE.

The Mt. Howe workings are situated two and a half miles n north-east of Mt. Howe Trigonometrical Station, and at the ape an arm granite invading the greenstone from Mt. Celia.

Fig. 33.

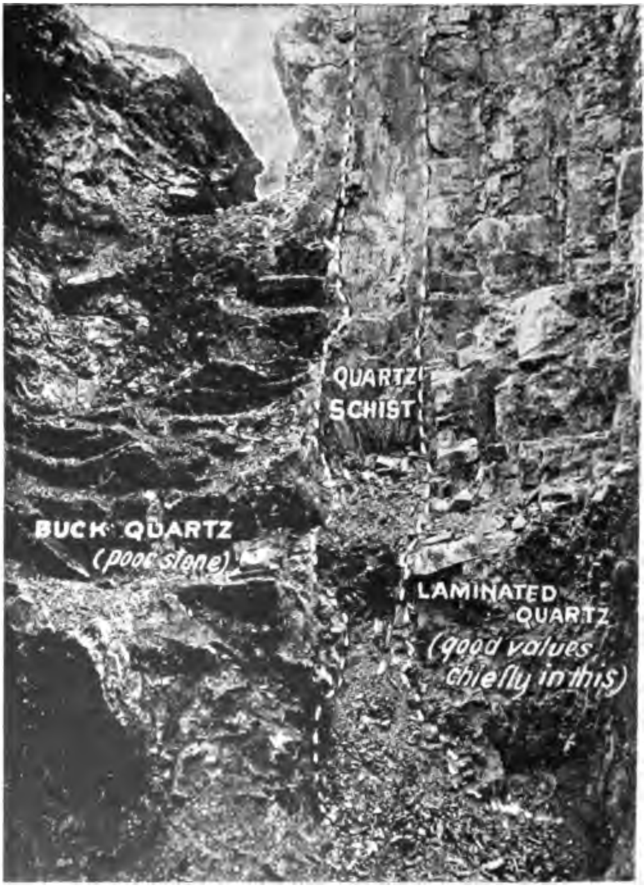


Photo.: C. S. Honman. Neg. 1380.

Lode on the Wallaby line of reef, Yarri.

The alluvial gold at Mt. Howe appears to have been shed f a quartz reef striking north-east and dipping north-west and oc ring on or close to the contact with the greenstone and granite. great deal of contact metamorphism appears to have taken plac the greenstone.

There is no record of the amount of alluvial gold won. I have heard from different sources that the richest claim did not exceed [illegible]ozs., and it is doubtful whether the total reached 1,000ozs.

Fig. 34.

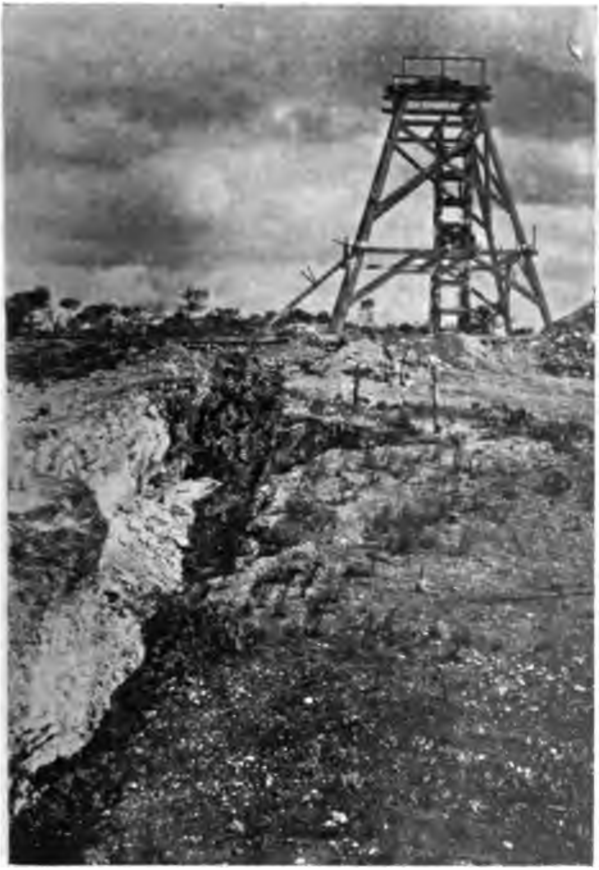


Photo.: C. S. Honman. Neg. 1381.

Main shaft and Open cut on the Wallaby lease, Yarri.

YARRI, EDJUDINA, AND PINGIN.

Not much development has occurred at these centres since 1905 (Fig. 33), when Mr. Maitland (the Government Geologist) reported on the Yerilla District[1], and Mr. Montgomery (State Mining Engineer) in 1903 and 1905[2]. (Fig. 34.)

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[1] Bulletin 11, G.S.W.A.

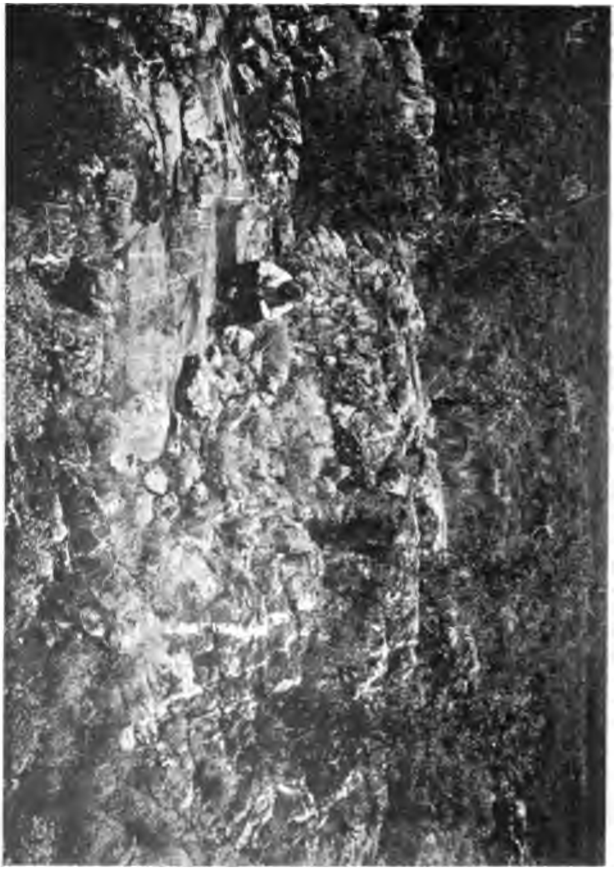
[2] Annual Reports of Mines Dept. for 1903 and 1905.

Prospectors have continued to obtain rich parcels of ore the kidney reefs of Edjudina. These reefs have been fully desc by Mr. Maitland, and his report is accompanied by a map.

At the time of my visit the Senate mine were taking out a c ing from the north end of old Senate lease, and since obtai very good return.

The payable kidneys always seem to be associated with a phyry dyke, which is sometimes sheared. This porphyry ca found on nearly all the dumps along the line and can be trace the whole length of some of the leases.

Fig. 35.



At Yarri, there are some large bodies of quartz, but they so far proved to be too low grade to pay. (Fig. 35.)

Pingin is a continuation of the Edjudina line. The line breaks through the ferruginous quartzite near the 12-mile Bore Well at Stephen's Well, where some gold has been obtained from a narrow reef in granite schist.

At Pingin the line of lode is on the east side of the Jasper Range, while at Edjudina it is west of the range. Kidney reefs occur at Pingin in schists similar to Edjudina.

MT. REMARKABLE.

This centre is situated 10 miles slightly west of north of Yerilla. All the shows occur in a decomposed sheared porphyrite. The reefs are north and south and dip to the east. No prospecting is going on here, and from the work done the shoots are short. Some alluvial gold has been obtained in the gullies. This centre is remarkable for the absence of any elevation, even approaching the size of a mountain. There is a bit of high ground at the 10-mile post which is flanked by a line of breakaways to the east.

CONCLUSION.

The gold-bearing reefs and lodes of the Yerilla District occur almost exclusively in the greenstone belts, but if in granite, the greenstone contact is never far away.

The mining centres always occur in disturbed areas where there have been great shearing and faulting.

It is significant that the majority of the mining centres, in fact nearly all, are close to either one of two distinct lines of faulting and shearing:—

(1) The Mt. Celia-Yundamindera fault plane.

(2) The Edjudina-Yerilla fault plane.

The latter is not as distinct as the former.

There is practically no prospecting going on in the district outside the centre, and there has been very little since 1903, when Mr. Maitland stated:—

> "In view of the extent of what may be termed the Edjudina-Yundamindera mineral belt and the number of reefs actuallyoutcropping in addition to those actually worked, there seems to me to be sufficient ground to warrant rather more vigorous prospecting than would hitherto have apparently been the case."

Future prospecting should have the best chance of success if undertaken in the vicinity and on the strike of the two huge fault planes quoted above, and marked on the accompanying geological map of the district.

As regards alluvial mining, there is sufficient evidence to warrant the statement that there is a great extent of deep alluvial ground in the district which has been untouched. There is more than a probability that such deep ground contains auriferous leads, especially where it occurs in mining centres. The cheape way to prospect for deep ground and auriferous le be by putting down a series of bores across a sect where there is direct evidence of the presence of de there are many places in the district where such evi able. The chief difficulty is the absence of criteria ground can be recognised from surface indications same to all appearance in hand specimens, can cover and deep alluvial. Men specially trained to local e luvial geology would, therefore, be required to pick ing.

There is undoubtedly deep alluvial at Yundami shaft has been sunk through 20 feet of hard cement similar to the laterite capping to decomposed countr 20 feet this cement gradually changes into a white p feet the shaft goes through a sandy wash and, finally, bottom resting on granite schist at 45 feet from the

Of minerals other than gold, none have yet bee district. The following are the most likely to occur, but have so far not been ultilised.

TIN.—There is an extensive development of to the contacts of the central granodiorite belt. As often associated with tin oxide (cassiterite), and ma bearing pegmatites occur at the above contacts, it mig pectors to be on the look out for tin while prospecti

The belt extends from Yundamindera south thro between Mulgabbie and Pingin. The greatest develo maline was noticed in pegmatites on the shores of south-east of Mt. Percy, and hence southwards to bey mile east of Mt. Wallbrook, where some shows have al for gold; in the vicinity of 12-mile Bore Well on th and about three miles west of Pingin Well.

ASBESTOS.—There is a widespread occurrence o bestos in the serpentine rocks of the district. The se been defined on the accompanying map.

Two classes of this mineral occur—

(1) Long-fibred, with the fibres parallel wit

(2.) Shorter-fibred, with the fibres across the

The latter is believed to be the best quality in t of Western Australia.

All the occurrences of asbestos I saw were ve silicified, but I am of the opinion this is due to supe tion, and that if developed below the surface cons tities of commercial asbestos will be found.

Specimens were collected at the following places:—

(a) About two miles south-east of Pyke's Hill.

(b) Near the three mile post on the Yundamindera-Linden road.

(c) At Linden, north of the Lady Ethel, on the north fall of the quartz blow.

(d) On the west fall of Mt. Howe, Trig, and many other places, but always in serpentine country.

Magnesite.—This also occurs in the serpentine belts; a very good outcrop can be seen at the 12 mile-post, on the Yundamindera-Linden Road. It is similar to the magnesite now being mined at Bulong. A search of the serpentine belts should reveal the presence of other deposits of this mineral in the Yerilla District.

Common Opal.—This is very plentiful in the serpentine country, but so far no precious opal has been found.

Sulphides.—It is possible that sulphides will be found below the surface on the ironstone formation that passes through Hills R. 1 and R. 2, Mt. Ruth at Yilgangie and Yandangerie. Possibly copper sulphides may occur along this line. There is some copper staining along cracks in an amphibolite alongside serpentine rock, one mile north of Olympic G.M., at Linden.

Iron.—Mr. Maitland, in 1903, drew attention to the large iron deposits occurring in the Jasper (Ferruginous Quartzites) Ranges at Edjudina and Mt. Millicent. He pointed out that their inaccessible position robbed them of any economic value.

APPENDIX I.

GEOLOGICAL NOTES ON THE NEIGHBOURHOOD O GANGI, NORTH COOLGARDIE GOLDFIELD.

By J. T. JUTSON.

(With Two Maps and Two Figures, 36 and 37.)

CONTENTS.

INTRODUCTION .. ..
TOPOGRAPHY .. ..
GEOLOGY .. ..
MINING .. ..
Lodes .. ..
Alluvial Deposits .. ..

INTRODUCTION.

The following notes are the result of a few days spent vicinity of Yilgangi during the month of August, 1915. The mainly to a small area, of under a square mile in extent, s between two and three miles to the east of the main Yilgan which is about 50 miles south-east from Kookynie. In thi some old gold workings occur. Other portions of the distric visited, but as my colleague, Mr. C. S. Honman, is at pres gaged in mapping the whole of the surrounding country on scale, only such features as have come under my notice, and bear on the small area mapped by me on a larger scale, will touched upon. The general geology of the whole district cribed by Mr. Honman (*vide* previous pages).

TOPOGRAPHY.

The area discussed forms a high belt of country with a fall to the north, north-west, and north-east; a sharp fall west; and more moderate ones to the east and south. Thi belt is dissected into rather steep ridges and gullies, but beyo belt most of the country is a plain, broken by various isolat and ridges. A striking example of a ridge projecting sharply is the jasper-quartz line of hills about two miles to the e area under review, bounding the western side of a narrow large lake to the south-west. The highest point of this It. Ruth (Trig. Station W 18).

GEOLOGY.

broad aspects the geology of the district is comparatively Rock belts run in a general north-north-westerly direction. ween Quandong and Yilgangi (see small-scale locality gical map, Plates VII. and VIII.) is a belt of sediments. lude the rocks to be more particularly described in this re- est of Yilgangi is a parallel strip of greenstone stretching oyce, and again west of this, granite can be traced in a terly direction to the Menangina Rocks, which form a t outcrop of the same kind of rock. To the east of the ry belt, shown on the small-scale map, the rocks are prob- nstones, with granite intrusions, as at Yarri.

brief statement of the general geology is made merely to relations of the surrounding rocks to those described more below.

accompanying geological map (Plate VII.) shows the geo- he more detailed area. The rocks of this area, which com- small mining belt of Yilgangi, may be divided into sedi- d porphyries. The sediments are chiefly composed of true ry conglomerates, with finer grained rocks, the nature of discussed below.

conglomerates (Fig. 36) occupy the ridges of the high ibed above, and were first noted by Mr. A. Gibb Maitland, nt Geologist, during a traverse made by him in the early e year 1915. They probably have a width of at least half d a length continuously traced along their strike of about half miles. They have also been found about seven miles th-north-west, and also on the lake arm just to the east of r ridge mentioned above; but with these extensions we are further concerned. So far as observed the general strike nglomerates is about 350°, and this appears to be regular stent. Few sections are shown to indicate their dip, but ll ones that could be seen displayed the rocks as practi- ical.

conglomerate pebbles are very abundant, and very well nd water-worn. They vary in diameter from one half an ight or nine inches, and some few are much larger, one eing noticed 18 inches in diameter. Although the con- has apparently been subjected to strong stresses, the com- ebbles do not appear to have been stretched or flattened eat extent. They are, however, sharply fractured in places

by joints. Many flat pebbles occur, but their outlines are cons
to be mainly due to erosion during their formation. So far
amined, the pebbles are mostly composed of quartz-porphy
quartz-porphyrite. They also probably contain other igneous
but no quartz pebbles were noticed.

Fig. 36.

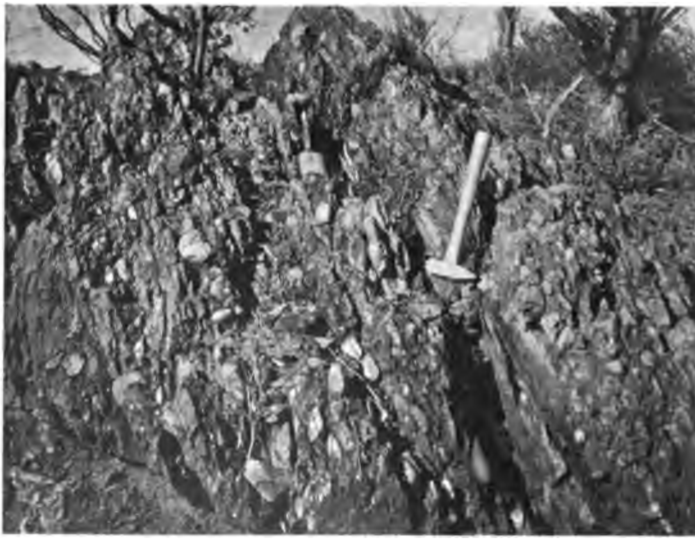


Photo.: J. T. Jutson. Neg.

Metamorphic Conglomerate, Yilgangi.

The matrix of the conglomerates is a tough, dense, gr
rather fine-grained rock, which, besides occurring immedi
around the pebbles, may be seen in bands up to about nine or t
inches thick, interbedded with and clearly forming part of th
posits represented by the conglomerates. This matrix has th
pearance of a rock of igneous origin. In hand specimens alo
would be so determined; but its association with the conglome
as a matrix, and its interbedded bands, suggest that it has bee
rived from either fine ordinary sedimentary material, or from
volcanic ejecta falling into the water containing the pebbles,
mixing with the ordinary sediments. In the field its appear
suggested that it was possibly a tuff.

As the question of the origin of the matrix was of import
in the light it might throw not only on the history of the cong
erates, but of other rocks elsewhere, two specimens from the

beds were submitted to the Petrologist for microscopical on. One $\left\lfloor \frac{1}{712} \right]$ represents an actual portion of the con- containing both pebbles and matrix, and the second s taken from a fine-grained band, about nine inches thick, ee from pebbles, in the conglomerates, this undoubtedly tion of the matrix. Both specimens were collected from ı of the old main road, west of the 30 mile post. The ic results are as follows:—

. Loc., south of the Old Road, near 30 M.P., Yilgangie:

·k greyish-green rock consisting of a rather fine-grained matrix rounded pebbles and angular fragments of different rocks.

'he specimen consists of a matrix enclosing large rounded ar rock fragments.

Matrix.—This is a rather fine-grained agglomerate consisting s of fine quartz-mosaic, brownish-yellow hornblende plates and gged, rounded and angular fragments of (a) a rock consisting small phenocrysts of felspar in a feathery felspathic ground- a feathery andesite or porphyrite.

Almost cryptocrystalline material heavily charged with minute epidote and zoisite, and with apparently a wavy flow structure.

)ccasional crystal plates of felspar and irregular platy calcite.

Elongated patches of minute feathery lath-shaped felspars vith zoisite and epidote granules and with phenocrysts of rellow hornblende.

Rounded fragments of a rock with phenocrysts of hornblende of felspar in a cryptocrystalline ground-mass in which, how- ure felspar laths can be detected.

Rounded fragments consisting of square tabular phenocrysts in a fine platy ground-mass of quartz and felspar.

Areas of microcrystalline and cryptocrystalline material heavily vith brownish-yellow chloritic scales and calcite grains and hes of quartz mosaic.

Portion of the matrix consists of a mass of quartz plates, ates, hornblende fragments and calcite grains and plates with as of microcrystalline mosaic.

An occasional irregular form of a fine-grained rock densely vith black dust and consisting apparently of minute laths of hlorite scales, and occasional calcite grains.

rock fragments, therefore, consist largely of andesitic varieties tz-porphyry or porphyrite.

Pebbles.—These include: (a) acid porphyry, quartz-porphyry, or ·phyrite.

Forms consisting of lath-shaped felspars of some size forming plexus of low birefringence with numerous small opaque grey aggregates and, rarely, chloritic scales. The rock is obscure but resembles certain facies of an andesite or porphyrite.

ock is a volcanic agglomerate matrix composed of large rounded ar crystals and crystal fragments of quartz, felspar, and horn- d small pieces of andesitic and porphyritic rocks, and enclos- larger rounded or angular pebbles of porphyry and porphyrite e.

$[\frac{1}{715}]$. Loc. as above:

A sheared fine-grained greyish-green rock with granular structure resembling that of arkoses or greywackes. There are few but distinct oval pebbles enclosed in the rock mass.

S. A fine-grained rock consisting of rounded microcrystalline mosaic areas—in one of which is a nest apparently of tourmaline needles—small rounded and oval areas of a somewhat feathery lath-shaped felspathic andesite, similar areas of a porphyritic rock with phenocrysts of felspar in a fine lath-shaped felspathic ground-mass, irregular forms of cryptocrystalline mosaic—at times finely micacised—granular and platy carbonate, crystal plates of quartz and felspar, all held together apparently by chloritic material in patches, and calcite, though cementing material is largely undifferentiated from the mass of the rock. The larger enclosed pebbles consist of a fine-grained mass of minute felspar laths with a fairly distinct parallel alignment, due probably to original flow structure. Numerous minute micaceous scales are scattered over this mass.

The rock, again, is an agglomerate, chloritic and partially carbonated, composed of small rounded portions of rocks generally very similar to those in $[\frac{1}{712}]$ but no hornblende crystals are visible in $[\frac{1}{715}]$, and the grain is finer. The occurrence of angular quartz plates and the general structure produce a close resemblance to an arkose, though in place of fragments of minerals there are rounded fragments of several rocks, and hence the rock is properly an agglomerate. In places, with an increase in the number of quartz fragments and mosaic areas, the resemblance to arkose becomes stronger.

Thus the matrix is a volcanic agglomerate with a tendency towards an arkose. The character of the pebbles shows that the rock as a whole is a true sedimentary conglomerate, and the explanation of the matrix is that fine volcanic material has been laid down under water with the ordinary fine sediments deposited amongst the pebbles. Later the whole rock mass has been changed into the present metamorphic conglomerate.

Associated with the main mass of conglomerate and apparently quite conformable to it on the flanks of the ridges are some finer grained somewhat gritty-looking rocks, which on field relationships are apparently metamorphosed sediments. They may be observed at the old workings in lease 802R (through which the new main road passes), and extend eastward from there for a considerable distance. They also apparently occur to the west of the main conglomerate outcrop, and in one place are possibly represented by a very schistose rock $[\frac{1}{713}]$ on a ridge just west of the 29 mile post on the old main road.

Some of these rocks have been examined by the Petrologist. The following is his description of $[\frac{1}{706}]$, $[\frac{1}{710}]$, $[\frac{1}{708}]$, and $[\frac{1}{707}]$.

$[\frac{1}{706}]$. Loc. Lease 802R; from Dump:

A dull greenish-grey somewhat sheared fine-grained rock.

S. There are apparent phenocrysts of felspar and crystals of quartz in a fine-grained microcrystalline ground-mass or matrix, which is obscured by granular and small platy calcite and minute sericitic scales in indistinct strings and aggregates as well as scattered greenish

scales. Both the felspar and quartz crystals, however, are
ı outline and appear as if broken. Occasionally, however,
ystals occur which appear almost quite euhedral, though, in
s, they are broken in pieces and granulated at the margins.
y they are much micacised and kaolinised. The quartz crystals
ally angular, sometimes triangular, at times long strips, at
ı broken, more or less granulated, margins. There are a few
icular aggregates and needles of rutile, while some of the
forms suggest an origin from pre-resisting ferro-magnesian
Occasionally there are elongated areas of minute mosaic, due,
to the break-down of a felspar or quartz plate.

nportant question is whether the rock is a sheared porphyrite
, and this, owing to the obscurity of the slides, is difficult to
.

rigin from a porphyrite is supported by:—

) The larger amount of the fine-grained matrix or ground-mass which makes up the bulk of the rock, its homogeneity and non-clastic structure—so far as it can be made out. It also resembles that of $\left[\frac{1}{714}\right]$ except for the pronounced sericitisation and carbonation in $\left[\frac{1}{706}\right]$. It certainly appears more closely resembling an igneous ground-mass than a matrix.

) The occurrence of felspar crystals appearing exactly as phenocrysts in a ground-mass.

evidence in favour of an origin from an arkose is:—

) The occurrence of rather frequent very angular crystals of quartz, which in nearly all cases have no idiomorphic boundaries, but are almost all triangular, or like long strips. It must be admitted, however, that, rarely, there is evidence of embayment of the quartz margins by the ground-mass.

) The occurrence of numerous truncated, broken and angular and wedge-shaped crystals of felspar.

) The fact that the undoubted porphyrites of the vicinity contain only rarely any quartz as phenocrysts.

sociation with this rock must be taken $\left[\frac{1}{710}\right]$ and $\left[\frac{1}{708}\right]$.

. Loc. as in $\left[\frac{1}{708}\right]$.

rk-grey, sheared, medium-grained rock with crystals of felspar
ron-stained spots, and grains of quartz visible to the naked

Consists of subhedral and ragged, large crystals of kaolinised
nd euhedral strips, and ragged rectangular crystals of quartz in
sericitised and chloritised more or less stringy scaly mass, in
all quartz veins are also visible. Many of the felspars are
, but many also stand out as "eyes," round which curve the
and chloritic strings. The mass in which the phenocrystal
embedded resembles a ground-mass rather than a matrix. A
semblance is to be noticed between this slide and that of $\left[\frac{1}{713}\right]$.
e latter is much sheared and almost slaty. The structure of
suggests much fracturing of the constituents.

. Loc. as in $\left[\frac{1}{710}.\right]$

uch finer grained pinkish-grey to brownish-grey sheared rock
same constituents as in $\left[\frac{1}{710}\right]$.

The general appearance of the slide is very similar to that of
t the ground is not well marked, and, though it is obscure from

sericitic and chloritic scales, it is less like an igneous ground-mass th the ground of $\left[\frac{1}{710}\right]$, but still unlike a matrix. There are also very lar anhedral quartz plates.

A peculiar feature of one slide is the occurrence in it of an appare oval pebble. In ordinary light the difference between the oval form a the surrounding material is, however, small. There is a more shear structure in the latter, a much smaller amount of greenish chlori rods, a greater amount of felspar phenocrysts, and occasionally are composed in some cases of numerous small, stout, lath-shaped turb phenocrysts of felspar in a minute ground-mass and apparently n sheared, in others of a microcrystalline ground, in which are small qua and felspar phenocrysts, in others of microcrystalline mosaic. In t oval form, however, which is intensely micacised as well as bestre with chloritic rods and grains of oxidised ferriferous carbonate, the are large and small areas of microcrystalline mosaic, rounded are formed of a mass of chloritic rods and scales and minute mosaic a apparent laths of felspar, now completely micacised and separated strings of micaceous scales. There do not appear to be, however, a large phenocrysts of felspar.

Without doubt, the appearance of the slide suggests a matrix e closing an oval pebble, though the continuation of the chloritic scal throughout the slide argues a continuity of the rock mass.

Sections at right angles to the shearing evidence extreme deform tion, cracking, granulation, and micacisation of the felspars and quar crystals, and drawing out of the chloritic rods and scales into strea lines. In places almost undoubted phenocrysts of partially granulitis quartz occur.

$\left[\frac{1}{707}\right]$. Loc. as in $\left[\frac{1}{710}\right]$.

A yellowish-grey, slightly sheared porphyritic rock with numero phenocrysts of felspar both large and small, many obviously sericitise

S. A highly porphyritic rock with numerous phenocrysts felspar in a microcrystalline ground-mass, in which also are numero small rounded iron-stained patches, ragged columns and granular aggr gates, doubtless representing the original ferro-magnesian.

The phenocrysts are, so far as can be made out, largely, if not a of plagioclase frequently exhibiting a zonal structure, and all turb from kaolinisation and micacisation; the felspar of the ground is large micacised, with a stringy arrangement of the scales round some of t phenocrysts. Quartz grains and occasionally coarse quartz mosaic a visible in the ground-mass.

The rock is a quartz-porphyrite, probably a facies of [$\frac{1}{71}$ sheared and altered by kaolinisation, chloritisation, and micacisation.

These are from a series of dumps in lease 802R on the Ne Yilgangi road; no field relations can be determined between the The microscopical examination gives no definite results. $\left[\frac{1}{708}\right]$ ma be either a sheared porphyrite or an arkose, and another $\left[\frac{1}{708}\right]$ su gests a matrix enclosing an oval pebble, although other consider tions argue a continuity of the rock-mass. $\left[\frac{1}{707}\right]$ is described as quartz-porphyrite, probably a facies of the porphyry to be describ below. The field evidence must decide the questions as far as po sible. As small dykes of the porphyry are found in the conglon erate, $\left[\frac{1}{707}\right]$ is probably an intrusive rock. With regard to t others, the general field evidence suggests that they are metamo phosed sediments, forming part of and being conformable to t conglomerates already mentioned, and being intersected by small dykes or veins of porphyry or porphyrite.

The following is the petrological description of $[\frac{1}{713}]$ which is from some distance to the west of the main conglomerate ridge:—

$[\frac{1}{713}]$ Loc., Ridge W. of 29 M.P., Old Road:

A grey, highly sheared, almost laminated slaty rock with numerous minute black knots on the shear surfaces.

S. The rock is best described for the present as a quartz-sericitic-chloritic phyllite. It consists of minute sericitic and chloritic strings separated by elongated quartz plates and with associated greenish chloritic scales, curving round frequent rounded chloritic forms, which now appear to be composed of chloritic scales in a quartzose mosaic, but which in places suggest a possible origin from felspathic forms. The resemblance to certain forms in $[\frac{1}{708}]$ has already been noted.

The sericitic strings are sometimes so dense as to form a sericitic felt, with the long axes of the scales parallel. They are generally curved, wavy, or contorted. The chloritic "eyes" are not uncommon, but their origin is not ascertainable with certainty.

The nature of the rock and its field occurrence (as part of the general sedimentary series of the district) also suggest that this rock has been derived from a sediment.

Various quartz reefs occur in the conglomerate, but none of any consequence has been worked. The reef in the old lease, 802R, upon which a fair amount of shallow work has been done, is in the fine-grained metamorphic sediments a few chains east of the conglomerate junction.

The porphyry (which has been described by the Petrologist (see below) as a hornblende-quartz-porphyry, partaking of the nature both of a quartz-syenite-porphyry, and of a quartz-hornblende-porphyrite) outcrops on the conglomerate ridges. and is no doubt largely responsible for such ridges by reason of its weathering-resisting power. It is a handsome, usually massive, grey rock, with white porphyritic crystals of felspar, up to three-quarters of an inch in size (Fig. 37). The following is the petrological description:—

$[\frac{1}{714}]$. Loc., south of Old Road, near 30 M.P.:

A dark-grey highly porphyritic rock with numerous large white felspar phenocrysts and innumerable smaller crystals in a dark-grey groundmass in which an occasional basic segregation can be seen. Rarely a small quartz crystal is visible. Some of the felspar phenocrysts exhibit an indistinct structure.

S. There are numerous large and small phenocrysts of felspar, numerous ragged prisms of greenish hornblende and greenish scales and aggregates of chlorite, and yellowish-green biotite in a minutely grained microcrystalline ground-mass of felspar and some quartz. Very rarely a large rounded phenocryst of clear quartz is visible. Minute scales of yellowish-green chlorite are scattered all over the slide as well as grains of sphene, epidote, and zoisite, while granular and small platy calcite is not uncommon.

The felspar phenocrysts are in some cases much kaolinised, in oth fairly fresh. The largest, however, are only slightly kaolinised, chie at the margins. Occasionally some are micacised or include yellow chloritic scales and granular carbonate. Two or three species are prese The more altered forms are usually a twinned plagioclase which, so as can be made out, is a rather basic oligoclase; in some cases, th exhibit a zonary banding. A striking peculiarity is the fact that largest phenocrysts show the characteristic gridiron structure of mic cline, are less kaolinised that the others, and frequently enclose euhed crystals—both large and small—of much kaolinised plagiocla showing both carlsbad and albite twinning. Moreover, in these lar phenocrysts, the presence of an albite intergrowth is revealed by difference in optical orientation of small patches in the crystal. So crystals of green hornblende and sphene granules are also in pla enclosed with the turbid plagioclase. The rock is a peculiar type, hig porphyritic, and from the acid nature of the felspars, the presenc though rare—of quartz phenocrysts and quartz in the ground-mass, a the presence of a considerable amount of hornblende, it partakes the nature both of a quartz-syenite-porphyry and of a quartz-hornblen porphyrite. It is put down as a **hornblende-quartz-porphyry.**

This rock would take a fine polish, and if more accessi would be of value as an ornamental stone. It frequently proje

Fig. 37.

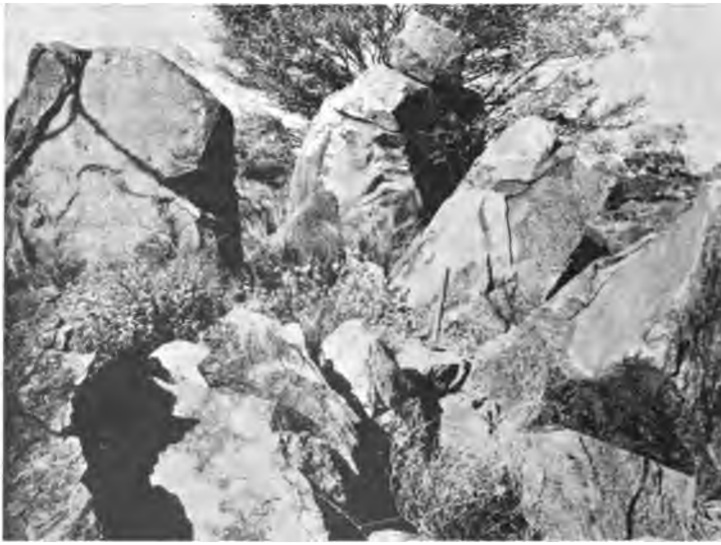


Photo. : J. T. Jutson. Neg. 1

Hornblende Quartz Porphyry, Yilgangi.

as small knobs, some of the boulders of which are somewhat roun owing to the rock weathering by exfoliation, and it is travers with more or less irregular joints. The mapping shows that the porphyry is intrusive into and therefore later than the conglomerate. At its southern end it has two tongues which unite a few chains south of the old main road, north of which it narrows and dies out about 20 chains to the west of lease 802R. In its general trend it is parallel to the strike of the conglomerate, and in places it is cleaved or foliated in the same direction. It varies in width from about four to 12 chains. Along the old main road west of the 30 mile post, a small patch of the conglomerate has been included in the porphyry, but beyond this no inclusions of the conglomerate or of its constituent pebbles were noticed, although they may occur without having been observed. The boundaries between the two rocks are as a rule quite sharp, and it seems probable that the conglomerate has been metamorphosed prior to the intrusion of the porphyry.

Some small quartz veins occur in the porphyry, and some have had a moderate amount of mining work done on them, but so far as could be seen, they appear to be more in the way of irregular leaders than well-defined quartz reefs.

The boundaries of the conglomerate and porphyry cannot be traced to the south, where the country falls, as sandy flats prevail, and prevent the determination of the underlying rocks.

In addition to the main mass of porphyry mapped, several small unmapped dykes occur.

MINING.

Lodes.—As already mentioned, the auriferous belt in Yilgangi appears to be very small. It is undoubtedly narrow, but there is a possibility of the extension of the lodes both to the north and to the south. If, however, they exist in either direction, they will not be easily discovered as the ground is lower and more or less covered with superficial deposits.

The lodes are quartz reefs, and somewhat irregular veins. They occur in the conglomerates, finer grained sediments, and the porphyry. As a rule they have not been mapped. The largest reef occurs in the finer grained sediments in lease 802R, and crosses the new main road. It is only a foot or two thick, and strikes a few degrees to the west of north parallel to the general strike of the conglomerates. It underlies to the west. This reef has been worked by an open cut, and by several underlay shafts, but apparently only to shallow depths. The country is very hard and tough, and the reef would require to be fairly rich to be payable under these conditions.

In the porphyry some quartz veins have been opened up, but so far as could be seen they are rather irregular and thin. They are not, therefore, likely to be permanent. Moreover, the country is tough right to the surface, and this makes the working cos Some shallow workings occur on the old main road about 25 cha west of the 30 mile post. More extensive workings, with seve shafts, occur about 30 chains to the south. Both veins strike proximately east and west, and underlie to the south.

Alluvial Deposits.—A few small patches have been turned o for alluvial, but evidently not much gold has been obtained.

Gold Yield.—The following table shows the gold yield of Yilgangi Mining Centre to the end of 1915. The average retur fairly good, but the quantity crushed is small:—

Table showing the Gold Yield from the Yilgangi Mining Cent

Year.	Name and Number of Lease.	Ore Crushed.	Gold therefro
		Tons (2,440lbs.)	Fine oz
1899 ..	Bush Boys, 439R	94·75	106·35
1903–4 ..	Yilgangie, 692R	79·00	169·49
1905 ..	Yilgangie, 802R	30·00	12·36
1907 ..	Mount Yilgangie, 854R ..	15·00	7·25
		218·75	**295·45**

Average per ton = 1·35 fine ozs.

(NOTE.—Lease 802R is part of the earlier Lease 692R.)

Summing up the mining, it may be said that little has b done, and that little more is likely to be done, as the reefs are regular, thin, and very hard country.

18th August, 1916.

APPENDIX II.

PETROLOGICAL NOTES ON SOME ROCKS FROM THE YERILLA DISTRICT, NORTH COOLGARDIE GOLDFIELD.

BY

R. A. Farquharson, M.A. (Oxon.), etc.

GROUP A.

[$\frac{1}{1062}$]. Loc.: Mt. Millbank.

A weathered amphibolised **dolerite** or **epidiorite**, with fibrous pale yellow-green hornblende more or less chloritised, small columnar opaque grey granular felspars and large patches of ilmenite in course of alteration to leucoxene. Quartz is apparently absent.

[$\frac{1}{528}$]. Loc.: Water Supply Paddock, Linden.

A fine-grained dark green rock. In section it is seen to be extremely decomposed, and to consist wholly of a minutely granular mass of felspar and quartz grains with numerous minute scales of yellowish and greenish chlorite, a few small grains and strips of calcite, a few wisps of pale grey-green chloritic material with fine associated calcite, and minute grains of iron ore and pyrites. In places there are one or two large columnar patches now reduced to a granular mass of quartz and felspar plates, which appear to have been phenocrystal felspars.

The characters of the rock are indistinct, and it is impossible to give a definite name to it. It may have been a fine-grained **amphibolite**, though the outlines of probable phenocrystal felspars suggest a **porphyrite**.

[$\frac{1}{1066}$]. Loc.: Peak, two miles south-west of 17-Mile Bore Well, Yundamindera-Linden Road.

Consists of small columns and grains of fresh augite separated by a large development of opaque grey columnar felspars with a few quartz grains and ilmenite and leucoxene plates, felspars, zoisitised, epidotised, and kaolinised. Rock best described as a **felspathic dolerite** with a little quartz, much highly altered felspar, and with some resemblance to augite andesites.

[$\frac{1}{1018}$]. Loc.: Half mile south-east of Hill R67, Lake Raeside.
A much weathered dark green rock with small yellowish carbonate crystals. In section it is much decomposed, and consists of scales and patches of green isotropic chlorite with plates and grains of a carbonate

that is ferriferous, large grains of black iron ore, small grain epidote, etc., all in an indistinct felspathic and to a smaller d quartzose mass, in which remains of columnar crystals of felspa be seen. The structure, though very indistinct, is suggestive of a dol

The rock is a highly **chloritised** and **carbonated amphiboli dolerite.**

[$\frac{1}{911}$]. Loc.: South-east corner of Cemetery Reserve, Y mindera.

Consists of a remarkably large number of large phenocrys augite, some with indistinct zoning, in a ground-mass compose minute laths of felspar, grains of augite of varying size, and small rounded grains frequently exhibiting cracks, a brown-red ation and straight extinction on the rare crystal boundaries. quite a number of these grains are undoubtedly augite, as prove the presence of cleavage, some exhibiting no cleavage are ref with doubt to olivine. The felspar laths in places, particularly the margin of the phenocrysts, exhibit distinct flow structure. augite appears in two generations, the phenocrysts and the grains of the ground-mass. The structure, especially of the gr mass, is that common in some basalts. The rock is **a finely porph basalt**, though from the large amount of augite it has some affi with augite lamprophyres or camptonites.

[$\frac{1}{890}$] Loc.: Hill three miles slightly south of east of S anis Well, Pinjin-Edjudina Road.

A fine granular limestone consisting of numerous small gra aggregates of a carbonate with a few interspersed grains of q and some scales of muscovitic mica with associated needles of r The limestone is in part dolomitic, in part calcareous, since it veseces in cold acid.

[$\frac{1}{999}$]. Loc.: North fall of Water Reserve Hill, Linden

A dense-black fine-grained somewhat soft rock, resembling black andalusite shales from the Kookynie-Niagara district.

S. Consists of a fine-grained dense-black granular mas which are numerous small squares, long and short laths, and aggre of squares of a colourless mineral. These latter forms prove to co of numerous highly birefringent mica scales to a small extent cha with black dust. On closer examination the fine-grained black is seen to be composed of indistinct highly birefringent plates si to the above but rendered nearly opaque by being densely charged a black graphitic dust. The determination of the forms is diffi The mica is evidently a decomposition product, since rarely some f without mica can be seen. These are of moderate refractive index biaxial, and so far as can be made out positive, but they may b some cases themselves decomposition products. The identity of mineral is doubtful. In the form of the crystals, in the decompos products, in the presence of amorphous carbonaceous grains, and i biaxial character, it rather resembles altered (micacised) andal though the apparent positive character of at least one plate is dif to explain, unless it is a decomposition product such as albite pr in the rock.

The rock is a black carbonaceous or amorphous **graphitic s** with a large development of a mineral referred with doubt to an site. It is, therefore, probably a contact metamorphic product an aluminous carbonaceous shale.

5. $[\frac{1}{317}]$. Loc.: Four miles west of Gabbro Hill, Edjudina.

A yellowish-white fragmental rock consisting of numerous small clear glassy quartz fragments united by a yellowish-white cement; somewhat banded and stained reddish by Fe_2O_3. S. Consists wholly of numerous angular and slightly rounded grains of quartz with rarely some kaolinised felspar in a kaolinic cement, white by light. The rock is a **kaolinic grit** with kaolinic cement.

$[\frac{1}{314}]$ Loc.: Wallaby Central, Yarri.

A dark-grey rather fine-grained rock with an incipient gneissic structure in very fine folia. Small grains of quartz and felspar are visible. The rock is rather strongly charged with pyritic ore.

S. (1.) Parallel to the foliation.

Minerals: quartz, felspar, green chlorite, brown chloritic biotite, epidote, zoisite, muscovite, calcite, pyritic ore.

(2.) At right angles to the foliation.

In these sections the rock consists of imperfect lenticular bands of quartz mosaic of varying length but non-continuous across the section, separated by generally thicker bands of a mixture of felspar plates, muscovite scales, grains and lenticular granular aggregates of epidote and zoisite, and scales and loose scaly aggregates of brown pleochroic chloritic biotite. The scaly constituents are all elongated in the same direction, they are generally in wavy or curved lines, and the epidotic grains also have their long axes parallel to the prevailing direction.

The latter, too, are frequently more or less completely surrounded by the brown scales. Green scales of chlorite are not common, and in places they are partially transformed to brown biotitic chlorite. In these micaceous bands, noteworthy are occasional crystals of felspar, both twinned and untwinned, sometimes kaolinised, sometimes micacised and lying at varying angles to the general direction of elongation. In places they present distinctly the appearance of augite, micaceous scales sweeping round them in curves, and there is a slight granulation of their margins, as well as in places an incipient granulation of the whole crystal. In some cases, moreover, the crystals are distinctly eye-shaped, and with granulation at the corner of the eyes.

The species of felspar present are difficult-to make out owing to the alteration and deformation, but some plates appear to be orthoclase, others, with small extinction angles on symmetrical lamellae, are either albite or oligoclase. Irregular extinctions, and irregularities (bending and fracturing) in the lamellation are noticeable in places. At times, epidote grains and calcite grains appear in the crystals.

The quartz is usually present in elongated lenticles or bands of coarse mosaic, but the constituent crystals of the bands are occasionally long rectangular, the long axis parallel to the general direction of elongation.

The micaceous bands have doubtless been produced from the decomposition of original felspar (some portions being a minutely scaly mass of fine muscovite scales).

It will be obvious from the foregoing that there has been dynamic deformation of the rock resulting in the production of "augen," of bends and cracks of the felspar lamellae, of granulation of the felspar, and probably of biotite from pre-existing chlorite.

The iron ores are pyrites in irregular grains and small strings, and apparently a black oxide which has been referred to ilmenite owing to the production by alteration of a grey-white (by incident light) decomposition product referred to leucoxene. These ores are associated with the muscovite-biotite-epidote bands.

The elongated rectangular form of some of the quartz cry
in bands suggests that the quartz banding is a primary feature.

The rock is a **micaceous epidotic granitic gneiss** with inci
minute foliation in quartz and altered felspar bands.

[$\frac{1}{315}$]. Loc.: Wallaby Central, Yarri.

Is the same rock as [$\frac{1}{314}$] but with the felspathic bands
distinct and less altered, the felspar being generally slightly ka
ised, though in parts much micaeised, the "augen" structure
marked, and with much less granular epidote associated with the
spar, though calcite grains are not uncommon. Granulated and
felspar plates, uneven extinction in some of the quartz crystals,
bending of lamellae in the felspars are as readily recognisable
$\frac{1}{314}$].

[$\frac{1}{316}$ Loc.: Wallaby Central, Yarri.

A fine-grained grey rock very finely foliated, the folia consi
of quartz and sericitic mica, with fairly numerous grains of ye
pyrites between the quartz leaves.

S. Similar to [$\frac{1}{314}$], but more closely resembling [$\frac{1}{315}$].

The rock consists of elongated lenticules and imperfect band
coarse quartz mosaic, separated by bands of a dense aggregate of co
less muscovite (sericite) scales amongst which crystals of altered fel
grains of zoisite, and colourless epidote, and felspar and quartz m
can be seen at times. There is a tendency towards the "augen" stru
in the relation of the muscovite scales or threads to the occasi
ungranulated or only partially granulated felspar plates. The l
are the same as in [$\frac{1}{314}$] and [$\frac{1}{315}$]. As in [$\frac{1}{315}$], there is much
epidote or zoisite in the slide, and the brown biotitic flakes are
tically absent, while calcite is in very small amount and in very s
grains. Pyrites in small grains is not uncommon.

The rock is a finely **foliated muscovite gneiss**, made up of band
quartz mosaic and a mixture of felspar plates more or less micae
kaolinised and granulitised, generally rendered all obscure by d
wavy aggregates of muscovite (sericite) scales in parallel alignm
Grains of zoisite are not uncommon in the micaceous aggregates.

LDFIELD, AS REPORTED TO THE MINES DEPARTMENT.

Total Production.

	luvial.	Dollied and Specimens.	Ore treated.	Gold therefrom.	Silver.
	ne ozs.	Fine ozs.	Tons (2.240lbs.).	Fine ozs.	Fine ozs.
Ed					
	..	..	97·50	76·06	..
	..	..	277·55	338·88	..
	..	..	246·00	165·20	..
	..	..	391·00	356·57	..
	..	..	166·50	42·52	..
	..	21·26	2,601·50	2,173·06	..
Eu					
	..	367·50	362·50	381·82	..
Li					
	..	..	148·20	169·30	..
	..	..	1,462·50	531·95	..
	..	..	803·00	874·12	..
	..	9·01	1,960·25	4,354·18	..
	..	..	51·25	48·06	..
	..	..	67·75	20·30	..
	..	6·11	984·75	914·30	..
	..	22·00	157·75	222·72	..
	..	..	266·25	573·79	..
	..	..	54·00	45·06	..
	..	..	1,995·00	1,452·42	..
	77·81	35·11	6,068·00	4,443·52	..
Mt					
	..	..	5·00	11·13	..
Mt					
	..	..	4·00	1·32	..
Pi					
	..	..	6,313·90	5,213·88	..
	..	99·36	3,235·35	2,160·50	..
Ya					
	..	..	838·00	1,679·35	2·00
	..	..	467·00	633·60	..
	..	..	845·50	147·08	..

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APPENDIX IV.

TABLE SHOWING THE PRODUCTION OF GOLD AND SILVER FROM VOIDED LEASES IN THE YERILLA DISTRICT, NORTH COOLGARDIE GOLDFIELD, AS REPORTED TO THE MINES DEPARTMENT.

Mining Centre.	Voided Leases.		Total Production to end of 1915.				
	Number of Lease.	Registered Name of Company or Lease.	Alluvial.	Dollied and Specimens.	Ore Treated.	Gold therefrom.	Silver.
			Fine ozs.	Fine ozs.	Tons (2,240lbs.)	Fine ozs.	Fine ozs.
Edjudina ..	681R	Alpha	..	..	33·50	19·03	..
Do. ..	989R	Anchor	..	..	25·00	8·24	..
Do. ..	204R	Anglo Saxon G.M. Co.	..	..	28·00	20·05	..
Do. ..	640R	Belgrave	..	..	85·00	27·82	..
Do. ..	527R	Bella	..	..	224·00	278·80	..
Do. ..	609R	do.	..	..	100·00	99·76	..
Do. ..	686R	do.	..	..	284·50	193·93	..
Do. ..	506R	Big Ben	..	..	30·00	7·94	..
Do. ..	961R	Blue Wing	..	..	25·00	19·47	..
Do. ..	773R	Box of Tricks	..	..	85·50	69·14	..
Do. ..	513R	Brilliant	..	..	30·00	50·13	..
Do. ..	610R	Broken Hill	..	..	85·00	58·37	..
Do. ..	611R	Broken Hill North	..	..	17·00	4·13	..
Do. ..	725R	do.	..	..	56·00	67·49	..
Do. ..	667R	Bulger	..	..	27·75	14·58	..
Do. ..	826R	Bunyip	..	..	61·00	132·57	..
Do. ..	676R	Cheetana	..	..	25·00	1·79	..
Do. ..	982R	Christina	..	..	56·17	26·20	..
Do. ..	543R	Concordia	..	..	28·00	7·75	..
Do. ..	813R	Coster	..	..	70·00	44·25	..
Do. ..	969R	Crow's Nest	..	..	402·75	278·97	..

PRODUCTION OF GOLD AND SILVER FROM THE YERILLA DISTRICT, NORTH COOLGARDIE G.F.—*continued.*

Mining Centre.	Voided Leases.		Total Production to end of 1915.				
	Number of Lease.	Registered Name of Company or Lease.	Alluvial.	Dollied and Specimens.	Ore Treated.	Gold therefrom.	Silver.
			Fine ozs.	Fine ozs.	Tons (2,240lbs.)	Fine ozs.	Fine ozs.
Edjudina	576R	Crow's Nest	..	..	635·00	759·14	..
Do.	401R, 500R	Edjudina Goldfields, Ltd.	..	..	1,266·10	926·61	..
Do.	589R	Enterprise	..	..	22·00	11·05	..
Do.	604R	do.	..	..	48·00	18·52	..
Do.	552R	Eva	..	..	29·00	47·00	..
Do.	678R	Fabian	..	..	40·00	25·15	..
Do.	713R	Federal	..	..	19·00	21·69	..
Do.	980R	Flavian	..	..	158·00	62·16	..
Do.	497R	Gawler	..	..	130·00	173·15	..
Do.	1016R	Gawler Extended	..	..	14·33	10·50	..
Do.	418R, 497R	Gawler G.M. Co., Ltd.	..	..	1,505·50	2,641·43	..
Do.	964R	Gawler South	..	..	38·50	32·10	..
Do.	502R	Glengarry	..	..	359·00	209·88	..
Do.	892R	Glory Quayle	..	..	15·00	7·96	..
Do.	588R	Golden Girl	..	..	94·00	90·07	..
Do.	968R	Golden Lizard	..	10·41	469·33	415·50	..
Do.	503R	Heathcote	..	..	72·00	33·51	..
Do.	573R	Highland Mary	..	..	130·00	137·93	..
Do.	948R	do.	..	..	186·50	161·22	..
Do.	847R	Jack Wren	..	..	217·50	250·88	..
Do.	502R, 545R, 571R, 583R, 584R	London and Coolgardie Explorers, Ltd.	..	..	283·00	217·34	..

Do.	512R	Lord Nelson	..	..	238·00	201·40	..
Do.	501R	Louie Mary	..	..	130·00	229·28	..
Do.	677R	Lyon Glen	..	..	182·00	161·49	..
Do.	653R	Maid Marion	..	..	17·00	10·72	..
Do.	1009R	Marama	..	..	81·00	42·38	..
Do.	460R	Mt. Eivesley	..	..	55·00	54·83	..
Do.	401R	Neta	..	..	4,280·50	5,466·29	..
Do.	418R	Neta Extended	..	..	61·50	48·61	..
Do.	418R	do.	..	..	1,182·50	1,421·81	..
Do.	401R, 418R, 497R, 500R	Neta Leases	..	..	5,217·00	9,968·12	34·58
Do.	401R, 500R	do.	..	..	1,274·50	1,264·91	..
Do.	715R	Never Can Tell	..	..	63·00	87·74	1·00
Do.	459R	Ninety Nine	..	..	30·00	9·39	..
Do.	872R	Old Edjudina	..	..	24·00	13·73	..
Do.	934R	do.	..	..	22·50	49·66	..
Do.	623R	Old Guard	..	..	41·00	51·83	..
Do.	648R	Orient	..	..	81·50	48·73	..
Do.	711R	Orphan Boy	..	..	48·00	35·43	..
Do.	523R	Outcast	..	..	60·00	61·69	..
Do.	981R	Parisian	..	..	14·66	4·76	..
Do.	613R	Perseverance	..	..	122·00	141·77	..
Do.	782R	do.	..	..	45·00	32·66	..
Do.	679R	Rocky Range	..	..	8·00	8·49	..
Do.	566R	Scotchman	..	..	341·00	229·89	..
Do.	701R	Scots Belle	..	..	39·50	45·68	..
Do.	987R	Senate	..	..	46·00	80·29	..
Do.	539R, 557R	Senate Leases	..	..	4,605·50	8,666·63	..
Do.	774R	Success	..	..	53·00	16·27	..
Do.	599R	Three Brothers	..	..	93·00	69·03	..
Do.	944R	Three Crosses	..	..	89·00	172·97	..
Do.	626R	Trio	..	..	35·00	10·28	..
Do.	605R	Triumph	..	..	232·00	103·36	..

PRODUCTION OF GOLD AND SILVER FROM THE YERILLA DISTRICT, NORTH COOLGARDIE G.F.—*continued.*

Mining Centre.	Voided Leases.		Total Production to end of 1915.				
	Number of Lease.	Registered Name of Company or Lease.	Alluvial.	Dollied and Specimens.	Ore Treated.	Gold therefrom.	Silver.
			Fine ozs.	Fine ozs.	Tons (2,240lbs.)	Fine ozs.	Fine ozs.
Edjudina ..	13R, 14R, 15R, 16R, 17R, 18R, 244R	Triumph Leases, Ltd	..	..	2,262·00	1,946·40	..
Do. ..	712R	Triumph South	..	..	60·00	62·01	..
Do. ..	665R	Try It	..	..	21·00	7·72	..
Do. ..	841R	Turn of the Tide	..	3·65	122·00	99·15	2·21
Do. ..	510R	Undaunted	..	..	65·00	55·47	..
Do. ..	498R	Vulcan	..	..	250·00	156·01	..
Do. ..	658R	Yale Lock	..	..	56·00	39·93	..
Eucalyptus ..	775R	Battlers Rest	..	37·42	9·00	41·50	..
Do. ..	491R	Brown Hill	..	47·87	7·00	54·65	..
Do. ..	721R	Call-me-early	..	91·89	2·50	63·96	..
Do. ..	538R	Cardigan	..	..	13·00	151·99	..
Do. ..	442R	Chesepeake	..	..	10·00	6·29	..
Do. ..	520R	Cornucopia	..	..	42·00	13·73	..
Do. ..	530R	Golden King	..	65·79	2·00	25·73	..
Do. ..	563R	Harlech Castle	..	1,026·41	7·00	93·22	..
Do. ..	426R	Ironsides	..	..	60·00	22·79	..
Do. ..	416R	Keep-it-Dark	..	107·49	24·00	76·46	..
Do. ..	505R	Knight Errant	..	42·86	12·00	19·69	..
Do. ..	371R	Lady Pascoe	..	..	10·00	3·88	..
Do. ..	100R	Nine of Hearts	..	..	848·00	803·71	..
Do. ..	803R	do.	..	..	..	76·97	..

Do	477R	Scotchman	..	58·83	2·35	33·48	..
Do.	521R	Shannon	..	..	3·00	5·29	..
Do.	315R	Shannon G.M. Co., Ltd.	..	..	186·00	110·58	..
Do.	698R	St. Patrick	..	..	19·50	65·05	..
Do.	400R	Unity	..	..	20·00	12·68	..
Do.	504R, 507R	Yando leases	..	1,386·21	74·00	1,416·00	..
Linden	966R	Alawa	..	..	26·00	3·18	..
Do.	1025R	Andy Fisher	..	..	148·20	169·30	..
Do.	864R	Bell	..	..	108·50	39·45	..
Do.	188R, 196R	Blair Athol Leases	..	..	113·00	363·41	..
Do.	399R	Burgess' Luck	..	413·13	27·00	52·97	..
Do.	413R	Caledonian	..	..	73·00	44·79	..
Do.	951R	Camel Back	..	..	291·00	189·09	..
Do.	901R	Carmen	..	..	126·00	39·27	..
Do.	965R	Danube	..	..	803·00	874·12	..
Do.	915R	Devon Deep Levels	..	..	62·50	35·75	..
Do.	898R	Dreadnought	..	..	199·50	183·41	..
Do.	949R	Dreadnought South	..	..	28·00	14·24	..
Do.	1019R	Edna	..	..	51·25	48·06	..
Do.	464R	Federal	..	13·84	97·60	230·59	..
Do.	978R	do.	..	..	127·50	68·75	..
Do.	123R	Golden Ridge	..	·72	10·00	5·07	..
Do.	888R	do.	..	..	29·00	11·20	..
Do.	967R	do.	..	..	28·00	21·23	..
Do.	928R	Great Carbine	7·53	..	1,721·00	1,117·57	..
Do.	406R	Great Carbine: Greenhill G.M. Co., Ltd.	..	..	294·00	160·37	..
Do.	914R	Green Hills	..	..	110·00	114·75	..
Do.	408R	Greenhill G.M. Co., Ltd.	..	..	3,198·00	5,783·68	..
Do.	897R	Hoffnung	..	..	38·00	50·22	..
Do.	921R	Jack and Doris	..	..	28·00	66·65	..
Do.	414R	Kangaroo	..	..	18·05	7·82	..
Do.	911R	do.	..	..	42·00	15·89	..

PRODUCTION OF GOLD AND SILVER FROM THE YERILLA DISTRICT, NORTH COOLGARDIE G.F.—*continued.*

Mining Centre.	Voided Leases.		Total Production to end of 1915.				
	Number of Lease.	Registered Name of Company or Lease.	Alluvial.	Dollied and Specimens.	Ore Treated.	Gold therefrom.	Silver.
			Fine ozs.	Fine ozs.	Tons (2,240lbs.)	Fine ozs.	Fine ozs.
Linden ..	917R	Keystone	..	..	69·50	30·46	..
Do. ..	384R	Lady Edith	..	..	105·50	405·37	..
Do. ..	387R	Lady Ethel	..	6·21	816·25	1,099·28	..
Do. ..	861R	do.	..	8·12	247·00	174·17	..
Do. ..	123R, 188R, 196R, 320R, 384R	Lake View and Boulder East G.M. Co., Ltd.	..	..	728·00	972·74	..
Do. ..	937R	Linden Star	..	1·70	165·50	218·95	..
Do. ..	685R	Mammoth	..	..	..	103·87	..
Do. ..	939R	Maudsley	..	..	241·50	198·80	..
Do. ..	963R	do.	..	..	17·50	14·89	..
Do. ..	877R	Moree	..	..	10·00	6·17	..
Do. ..	430R	Mountain Maid	..	..	3·50	3·62	..
Do. ..	357R	Mt. Wilgress	..	..	9·00	6·68	..
Do. ..	972R	New Year's Gift	..	..	353·50	284·37	..
Do. ..	407R	New Year's Gift G.M. Co., Ltd. ..	..	..	176·00	109·41	..
Do. ..	940	Oakover	..	..	39·00	18·54	..
Do. ..	881R	Oldfield Proprietary	..	..	44·50	163·49	..
Do. ..	468R	Recovery	..	..	8·00	46·60	..
Do. ..	869R	Rock	..	52·57	12·00	70·69	..
Do. ..	988R	Sand King	..	..	100·00	24·28	..
Do. ..	938R	Success	..	..	9·00	8·89	..
Do. ..	420R	Travellers Joy	..	..	71·00	97·60	..
Do. ..	285R, 286R ..	True Blue Leases	..	16·04	38·00	44·57	..

Do. ..	295R	True Blue Jacket			12·00	10·67	..
Do. ..	358R	Wimmera	..	3·71	416·50	540·35	..
Do. ..	862R	do.	..		137·50	75·66	..
Mt. Celia	434R	Wongililly Proprietary	..	..	14·00	5·39	..
Mt. Remarkable	375R	Darlot Exploration Co. of W.A., Ltd.	..	..	22·00	10·59	..
Do. ..	448R	Excelsior	..	..	10·00	4·91	..
Do. ..	515R	Federation	..	..	81·75	59·68	..
Do. ..	519R	Golden Emu	..	..	5·25	2·21	..
Do. ..	445R	I.X.L.	..	4·49	26·50	11·10	..
Do. ..	397R	La Tosca G.M. Co., N.L.	..	13·25	383·22	326·60	..
Pingin ..	809R	Ancient Briton	..	..	35·00	10·64	..
Do. ..	738R	Anglo Saxon North	..	..	404·80	306·91	..
Do. ..	886R	do.	..	..	363·50	234·79	..
Do. ..	739R	Australasia	..	..	139·00	78·14	..
Do. ..	795R	Binberry	..	..	13·90	5·02	..
Do. ..	465R	Bobadil	..	..	17·00	30·83	..
Do. ..	772R	Cardjella King	..	..	107·00	28·11	..
Do. ..	910R	Coles	..	..	1,327·50	417·10	..
Do. ..	974R	Coronation	..	..	312·50	110·27	..
Do. ..	810R	Exile	..	..	24·00	10·15	..
Do. ..	824R	Fair Play	..	..	76·00	24·76	..
Do. ..	878R	Forgotten	..	..	61·50	45·35	..
Do. ..	816R	Harbour Light	..	..	123·70	187·84	..
Do. ..	816R, 817R ..	Harbour Light Leases	..	..	222·00	92·56	..
Do. ..	815R	Harbour Light North	..	..	146·00	228·59	..
Do. ..	906R	King Pin	..	..	611·50	660·19	..
Do. ..	953R	do.	..	..	60·00	28·39	..
Do. ..	839R	Lilian	..	..	50·00	53·14	..
Do. ..	845R	Lily of Australia	..	2·60	300·50	244·24	..
Do. ..	926R	Little Wonder	..	..	6·00	12·00	..
Do. ..	829R	Mary Jane	..	..	55·00	9·44	..
Do. ..	796R	Oaks	..	..	361·00	242·71	..
Do. ..	432R	Paragon	..	..	20·00	7·37	..

PRODUCTION OF GOLD AND SILVER FROM THE YERILLA DISTRICT, NORTH COOLGARDIE G.F.—*continued.*

Mining Centre.	Voided Leases.		Total Production to end of 1915.				
	Number of Lease.	Registered Name of Company or Lease.	Alluvial.	Dollied and Specimens.	Ore Treated.	Gold therefrom.	Silver.
			Fine ozs.	Fine ozs.	Tons (2,240lbs.)	Fine ozs.	Fine ozs.
Pinjin ..	812R	Pingin Queen	..	..	108·50	138·75	..
Do. ..	761R	Pingin Consols	..	..	131·00	104·61	..
Do. ..	754R	Pingin King	..	10·45	1,686·50	883·53	..
Do. ..	751R	Pingin Main Reef	..	33·94	95·00	37·82	..
Do. ..	863R	Pingin North	..	..	161·50	155·62	..
Do. ..	873R	Poverty Hill	..	..	51·50	34·17	..
Do. ..	425R	Protest	..	..	10·00	4·49	..
Do. ..	832R	Shamrock	..	..	101·00	50·36	..
Do. ..	444R	Sirdan	..	..	95·00	36·63	..
Do. ..	932R	Undaunted	..	..	60·50	47·30	..
Do. ..	962R	Unification	..	..	624·00	333·22	..
Yarri ..	655R	Aerie	..	..	51·00	49·24	..
Do. ..	632R	Beatrice	..	..	50·00	45·90	..
Do. ..	730R	Britisher	..	..	13·00	11·88	2·00
Do. ..	788R	Dostmund	..	..	838·00	1,679·35	..
Do. ..	1017R	Golden Butterfly	..	..	49·50	71·68	..
Do. ..	857R	Golden Dyke	..	..	158·00	94·28	..
Do. ..	746R	Golden Wallaby	..	..	5·00	4·55	..
Do. ..	801R	Great Banjo	..	..	46·00	20·81	..
Do. ..	757R	Gwydir	..	..	130·00	46·68	..
Do. ..	736R	Homeward Bound	..	..	17·00	15·30	..
Do. ..	766R	Hiden Treasure	..	..	698·50	325·12	..
Do. ..	784R	Kismet	..	..	69·00	45·27	..

Do.	666R	Mia Mia	..	..	39·50	23·40	..
Do.	717R	Not-too-late	..	..	20·00	40·52	..
Do.	630R	Novitiate	..	15·87	..	..	..
Do.	777R	Penola	..	..	160·00	93·21	..
Do.	690R	Puzzle	..	..	41·75	149·37	..
Do.	882R	Quartz Ridge	..	..	38·50	45·36	..
Do.	585R	Queen's Birthday	6·30	14·94	492·00	798·35	..
Do.	614R	Queen's Birthday South	..	..	60·00	33·87	..
Do.	587R	Record	..	..	24·50	43·14	..
Do.	680R	Return	..	..	25·00	14·02	..
Do.	805R	Right Bower	..	..	33·00	39·01	..
Do.	631R	Star of the West	..	..	15·00	47·80	..
Do.	831R	Star of Yarri	..	..	247·50	89·99	..
Do.	830R	Venture	..	..	10·50	4·45	..
Do.	580R	Wallaby Central	..	..	2,411·00	2,335·30	..
Do.	580R	do.	..	14·91	1,852·50	681·94	..
Do.	999R	do.	..	..	845·50	147·08	..
Do.	580R	Wallaby Central : Lake View South, Ltd	..	..	10,109·00	4,488·20	..
Do.	579R	Wallaby North	..	..	1,854·50	565·54	..
Do.	919R	do.	..	..	1,229·50	426·91	..
Do.	960R	do.	..	..	730·50	225·06	..
Do.	635R	Welcome	..	..	81·00	63·61	..
Do.	936R	White Elephant	..	..	14·00	5·91	..
Do.	582R	Wild Dog	..	..	54·50	41·34	..
Do.	719R	Yarrie	..	..	5·00	5·36	..
Do.	737R	Yarrie South	..	..	1,053·00	1,212·62	..
Do.	787R	Yes-No	..	..	64·00	93·50	..
Yerilla	828R	Artful Dodger	..	..	20·00	6·36	..
Do.	87R	Black Gin	..	..	63·00	36·71	..
Do.	427R, 87R	do	..	..	23·75	4·02	..
Do.	376R	Bonanza	..	23·90	5·60	15·11	..
Do.	238R	Bullion	..	..	158·00	17·35	..

PRODUCTION OF GOLD AND SILVER FROM THE YERILLA DISTRICT, NORTH COOLGARDIE G.F.—*continued.*

Mining Centre.	Voided Leases.		Total Production to end of 1915.				
	Number of Lease.	Registered Name of Company or Lease.	Alluvial.	Dollied and Specimens.	Ore Treated.	Gold therefrom.	Silver.
			Fine ozs.	Fine ozs.	Tons (2,240lbs.)	Fine ozs.	Fine ozs.
Yerilla	850R	Central East	..	..	244·00	166·12	..
Do.	867R	Central West	..	4·59	..	..	..
Do.	843R	Clan Donachaich	..	..	134·00	50·91	..
Do.	866R	Consolation	..	..	15·00	9·89	..
Do.	923R	Desert Queen	..	..	10·00	4·76	..
Do.	472R	Fenton South	..	..	30·00	11·46	..
Do.	451R, 354R	Gertrude	..	184·80	73·01	84·59	..
Do.	98R	Golden Grove	..	..	10·75	3·17	..
Do.	191R	Golden Star	..	..	142·00	79·92	..
Do.	436R, 193R	Harrow	..	..	28·80	8·28	..
Do.	378R	Jubilee	..	..	14·75	5·39	..
Do.	785R	King of the Earth	..	..	190·50	167·22	..
Do.	372R	Lady Florence	..	..	43·00	14·68	..
Do.	264R	Lady Gertrude	..	..	194·50	183·79	..
Do.	354R	Lady Gertrude South	..	..	9·00	2·81	..
Do.	305R	Lombard	..	..	..	31·19	..
Do.	1020R	Melba	..	..	50·00	22·29	..
Do.	458R, 89R	McGregor	..	..	22·75	35·35	..
Do.	836R	McGregor North	..	..	138·00	74·62	..
Do.	970R	Melba	..	..	279·50	62·88	..
Do.	682R	Melba Consols	..	..	570·50	300·13	..
Do.	682R	Melba Consols G.M. Co., N.L.	..	..	308·00	167·57	..
Do.	689R	Melba Proprietary	..	..			..

Do.	55R, 59R, 60R	Mt. Catherine: Mt. Catherine G.M. Co., Ltd.	..	..	321·00	92·95	..
Do.	110R	Ovens	..	..	86·00	97·01	..
Do.	902R	Possible	..	8·26	..	..	..
Do.	70R	Queen of the Earth	..	2,846·91	277·25	252·67	..
Do.	590R	do.	..	..	15·00	26·80	..
Do.	704R	do.	..	..	32·50	19·12	..
Do.	88R	Queen of the Earth, No. 8, North	..	2·00	..	..	..
Do.	89R	Queen of the Earth, No. 9, North	..	..	49·15	46·95	..
Do.	807R	Red Cross	..	..	43·00	18·54	..
Do.	180R	Rise Again	..	..	30·00	15·41	..
Do.	860R	Rookewood	..	·88	117·00	115·34	..
Do.	900R	Roscommon	..	..	50·00	14·71	..
Do.	693R	Viola	..	2·22	..	..	..
Do.	752R, 850R	Viola Leases (late Second Try)	..	9·64	2,164·00	1,958·48	8·21
Do.	975R	Viola South	..	·96	..	..	..
Do.	1001R	Westward Ho	..	..	267·50	130·04	..
Do.	684R	Yerilla Central	..	..	2,056·00	2,624·97	..
Do.	64R, 65R, 93R, 105R	Yerilla Claims, Ltd.	..	5·35	781·25	619·44	..
Do.	154R, 155R, 156R	Yerilla G.M. Co., N.L.	..	..	622·00	339·63	..
Do.	851R	Yerilla King	..	..	5,896·75	4,419·03	..
Yilgangie	430R	Bush Boys	..	..	94·75	106·35	..
Do.	854R	Mount Yilgangi	..	..	15·00	7·25	..
Do.	692R	Yilgangie	..	..	79·00	169·49	..
Do.	802R	do.	..	..	30·00	13·36	..
Yundamindera	562R	A.W.A.	..	18·40	620·00	1,172·75	..
Do.	931R	Battles Ville	..	..	2,481·50	639·88	..
Do.	508R	Boer	..	..	374·00	793·36	..
Do.	533R	Boomerang	..	..	52·00	50·60	..
Do.	117R	Bound to Rise	..	..	·50	248·61	..
Do.	1030R	Brown Hill	..	9·10	..	..	..
Do.	645R	Central	..	..	15·00	19·67	..

Production of Gold and Silver from the Yerilla District, North Coolgardie G.F.—*continued.*

Mining Centre.	Voided Leases.		Total Production to end of 1915.				
	Number of Lease.	Registered Name of Company or Lease.	Alluvial.	Dollied and Specimens.	Ore Treated.	Gold therefrom.	Silver.
			Fine ozs.	Fine ozs.	Tons (2,240lbs.)	Fine ozs.	Fine ozs.
Yundamindera	487R	Dewey	..	..	134·45	211·76	..
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LXI. Physiographical Geology of Western Australia: by J. T. Jutson, Field Geologist. (*Out of print*). 1914.

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paration :—

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he Geology and Mineral Resources of Western Australia: by A. Gibb Maitland.

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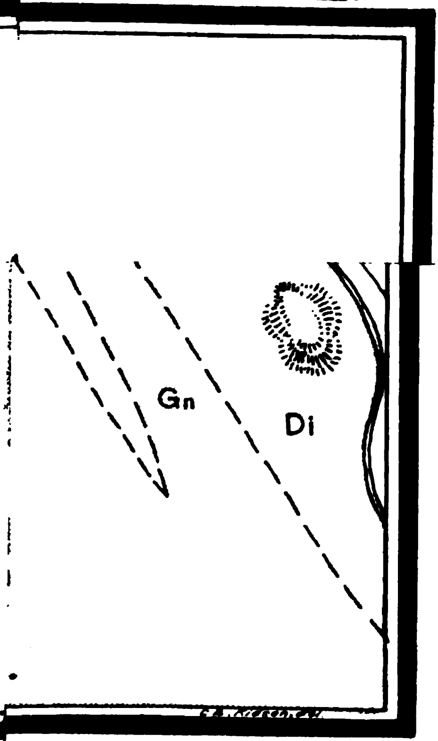

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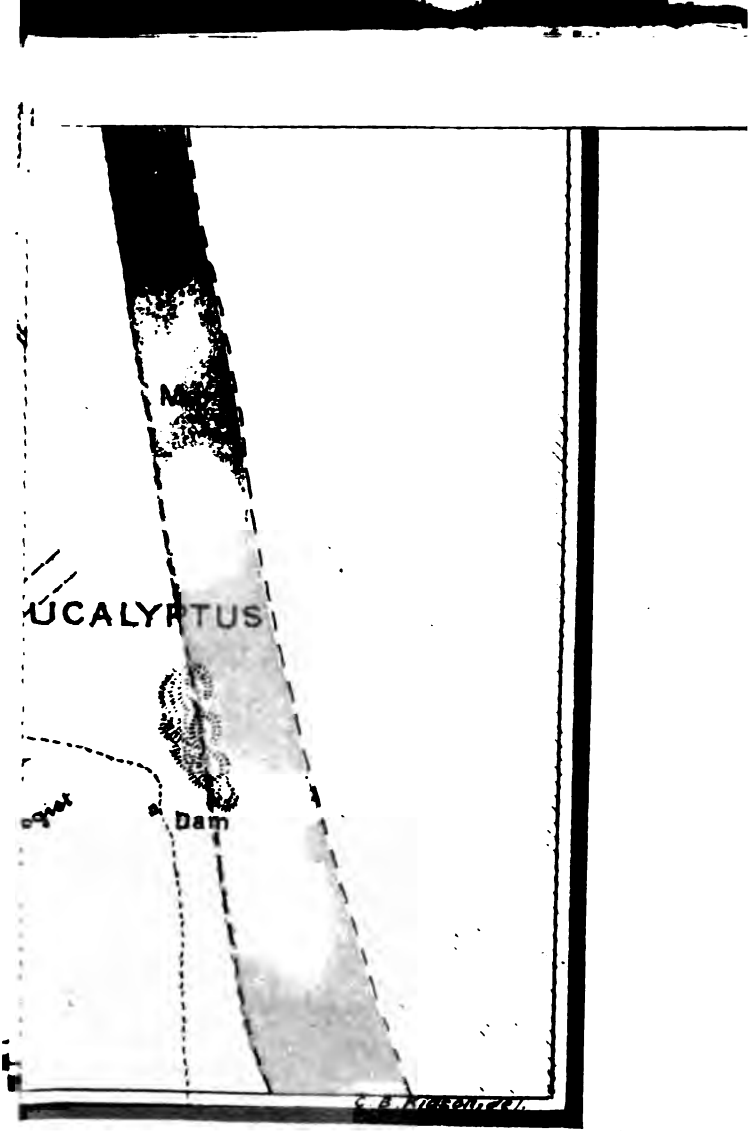

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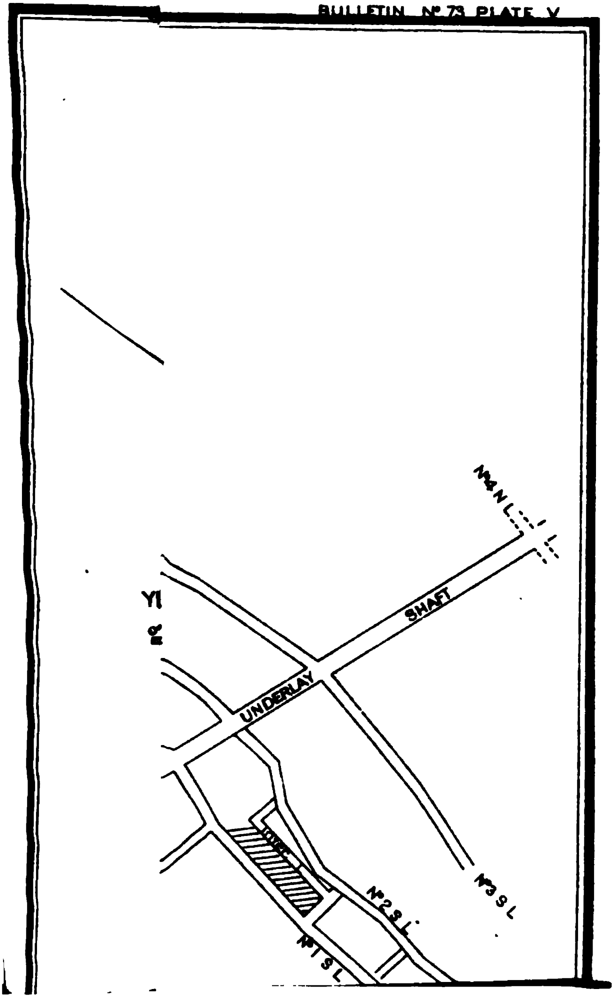

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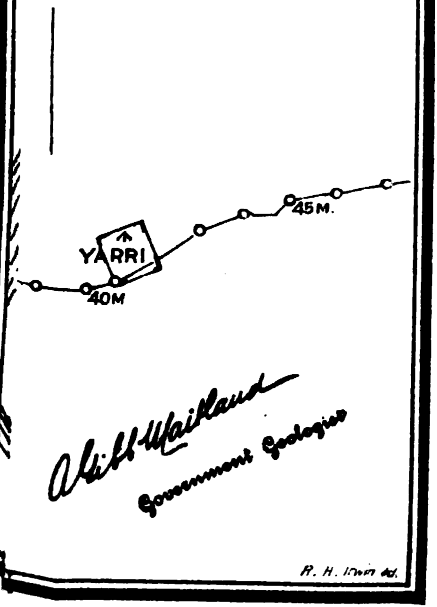

A Gibb Maitland
Government Geologist

R. H. Irwin del.

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The Hon R T Robinson, K.C. M.L.A.
Minister for Mines

GEOLOGICAL MAP OF
YILGANGI MINING CENTRE

N COOLGARDIE G. F.

BY

J. T Jutson, Field Geologist

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SCALE OF CHAINS

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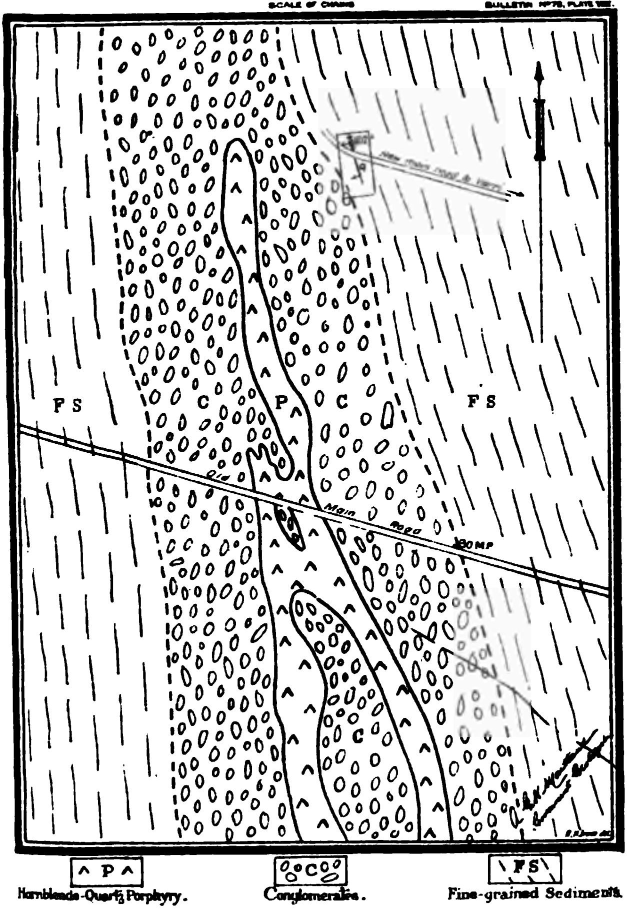

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1917.

WESTERN AUSTRALIA.

GEOLOGICAL SURVEY.

BULLETIN No. 74.

MISCELLANEOUS REPORTS.

SERIES V., Nos. 61-70.

ISSUED UNDER THE AUTHORITY OF
THE HON. R. T. ROBINSON, K.C., M.L.A., MINISTER FOR MINES.

WITH ELEVEN FIGURES AND EIGHT PLATES.

PERTH:
BY AUTHORITY: FRED. WM. SIMPSON, GOVERNMENT PRINTER.

1917.

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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA.

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Do.	E. de C. Clarke
Do.	F. R. Feldtmann
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General Assistant	B. S. Welsh

* Absent with Expeditionary Forces.

PREFATORY NOTE.

This volume makes the fifth addition to the series of Miscellaneous Reports which deal chiefly with the applied side of geology. The articles are, as usual, issued without being grouped, either according to localities or subjects.

The last collection of miscellaneous reports was contained in Bulletin 64.

A Gibb Maitland

GOVERNMENT GEOLOGIST.

Geological Survey Office,
Perth, 28th March, 1917.

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MISCELLANEOUS REPORTS.

SERIES V.

61.—THE PHOSPHATIC DEPOSITS OF WESTERN AUSTRALIA.

By H. P. Woodward.

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INTRODUCTORY.

Phosphatic deposits occur in four forms in Western Australia, iz., guano, both live and dead, upon the coastal hills and fringing lands; ferruginous phosphatised wood and coprolite beds of the andarragan district; amblygonite near Coolgardie; and cave uano deposits elsewhere.

Up to the present time the only deposits worked upon a comercial scale are the Island and Coastal Guanos, but of these all e material of sufficiently high grade for the manufacture of superhosphate has, as far as our present knowledge extends, been orked out; therefore the rock employed in the manufacture of is fertiliser at our local works has to be imported.

Up to the end of 1904 (after which year the export of guano as prohibited) 118,530 tons were raised, of which 105,754 tons, by ip's register (40 cubic feet), were shipped, the value placed upon was £338,732, of which amount the Government received in the way of royalty, special license fees and rent, £53,658. These figures clearly only represent a portion of the total quantity raised, since in the first place large quantities would appear to have been removed without the knowledge of the Government, and in the second, as guano raised for local consumption paid no royalty, a record was not always kept of this; while further, it will be noticed that in the returns supplied by the Customs the quantity exported is 18,268 tons less than that recorded by the Lands Department, which was responsible for issuing licenses and collecting the royalty.

What led up to the discovery of these deposits is not definitely known, but it was in all probability due to the American whalers who fished the Western Australian coast some 60 and 70 years ago; the reason for this surmise being that the earliest shipment on record went to the United States, while prior to these it was discovered that a very considerable quantity had been shipped to the same destination without the cognisance of the Government. In more recent years the bulk of the trade was with Germany and Belgium, and to a more limited extent with New Zealand, Victoria, Tasmania, and Mauritius.

The earliest official record extant of a shipment of guano is three tons in 1847, followed by further small parcels in 1855, 1865, and 1872; but no record exists of the locality from which these were obtained, while the labour involved in tracing the destination of these shipments would not be repaid by the information disclosed.

From the year 1876 onwards a pretty regular export trade appears to have been carried on, but although this guano was obtained from all the islands between the Ashmore Shoals and the Abroholos Islands, records are far from perfect. From the Ashmore Shoals, Browse Island, Jones Island (the latter being near Admiralty Gulf), and numerous other islands upon the north coast, much larger quantities of guano were probably raised than ever paid royalty, since as recently as 1885 it was reported to the Government that two ships and eight barques were seen loading at Browse Island, on which no return was furnished.

Large quantities of high-class guano must have been exported from Browse Island, as is evidenced by the fact that it is the only locality credited with deposits of this description in Western Australia in either British, American, German, or Colonial publications.

Messrs. J. and W. Bateman would appear to have chartered vessels which removed guano from the Lacepedes, Montebello, Barrow Island, etc., for a number of years prior to 1890, for they stated this fact in a letter addressed to the Government in support of their application to be granted the exclusive rights to work certain islands. No record of these, however, exists, and the present firm is now unable to furnish any particulars.

It would appear that Mr. F. L. von Bibra obtained the sole right to remove live guano from Shark's Bay, where he carried on a

erable business between the years 1880 and 1888, when some
e arising between him and other persons who claimed the right
ove dead guano, the Government's attention was drawn to the
hat he had not so far furnished returns of the quantity re-
, since he only supplied the local market, in which case no
y was chargeable. As he had, therefore, the monopoly to
a large area without contributing anything to the revenue in
, it was decided to renew his concession upon a rental basis.
er the deposits were exhausted, or the rent was too heavy,
ot transpire, but the working of them appears to have ceased
his date.

may be mentioned here that the term "live" guano was ap-
to fresh unaltered bird droppings, whilst "dead" guano was
estone which had become converted in part, or wholly, into
ic phosphate, due to the percolation of the soluble phosphates
he bird droppings. It is a very noticeable fact that nearly
guano raised was exported, while the small portion consumed
would in all probability prove (could we ascertain the fact)
e consisted almost entirely of live guano.

e fine-ground rock phosphate does not appeal to the average
in this State owing to the fact that it is slower in its action
uperphosphate, which, sown with the wheat, gives its maxi-
esult the first year. Ground phosphate rock is, however, of
alue in wet districts, hence the demand for this material in
, America, Victoria, Tasmania, and New Zealand, since it
oses rapidly in a soil rich in humus or peat.

ere is no doubt whatever that if ground phosphate rock or
os guano was applied in fair quantity to the wet lands
d in the south-western portion of this State it would pay the
better in the long run than the continual dressing with super-
ate as at present practised, for it would not only act as a
er for the immediate requirements of the crop without in-
g the acidity of the soil, but it would build up the land to
ing like a good standard grade, since at the present time
s little land under cultivation in this State which is not defi-
n phosphorus.

this connection the following facts may be of interest. The
s of 150 soil samples made by the Government Agricultural
t gives an average percentage of .041 of P_2O_5. These samples
ostly confined to the South-West, while the writer is indebted
Mt. Lyell Chemical Company for the results of 26 soil sam-
hich average .038 P_2O_5. If these are compared with the recog-
tandard of a good soil, which is .150 of P_2O_5, it will be seen
e how deficient in this most necessary ingredient these soils

s previously mentioned, so far as our knowledge goes, the
f the rock phosphate of a sufficiently high grade to manu-
e "super" has been worked out, but still there remains a vast

quantity of lower grade material which, if ground, would mirably suitable for application to the farming lands situ the wetter portion of this State.

This material, in addition to the phosphoric oxide, con small proportion of nitrogen, which adds to its value, wl main impurity is carbonate of lime, which substance is als needed in the majority of our soils.

INDIVIDUAL DEPOSITS.

JONES, LESUEUR, AND STEWART ISLANDS, AND BLACK HAWK

These islands, which lie between Lat. 13deg. 42min. and 45min. and Long. 125deg. 59min. and 127deg. 42min. are on the extreme north coast, appear to have been worked in th days of the Colony, but no record exists until the year 188 the Government estimated the deposits to consist of 50,000 guano containing 80 per cent. of tri-calcic phosphate, wl 1s: 9d. per unit, was worth £7 per ton. Upon the strength of exclusive license was issued to Messrs. Beaver & Co., of Mel to remove guano for a period of five years on a basis of 1 ton royalty. This firm removed 2,577 tons and paid £1, royalty and then abandoned their concession, stating that si balance contained 35 per cent. of carbonate of lime it was v for their purpose.

BROWSE ISLAND DEPOSIT.

This island, which is situated about 100 miles off the nor on Lat. 14deg. and Long. 123deg. 40min., has received the cr over the world of being a great producer of rock phospha sequently it is highly probable that considerable quantitie removed before the Colonial Government became cognisant fact, for it was not until the year 1873 that any mention o ists in the official records. In this year negotiations were by an Adelaide syndicate known later as the Browse Guano Co., to work this deposit, but no finality was arrived 1876, when an agreement was entered into for a period of 1 by which the Company should pay a yearly rent of £50 with a per ton royalty on all guano removed above 400 tons.

The Government appear to have had very great trouble taining statements from the Company, as no direct supervisi exercised; they were therefore entirely dependent upon the of the Company, about which apparently there were some since no returns were furnished for the years 1880, 1881, 18 1885, while during the last-mentioned year the master of a schooner reported that he had seen two ships and eight busily engaged loading; the return, therefore, of 23,177 ton which a royalty of £3,158 was paid, is probably far below th amount removed.

LACEPEDES GUANO DEPOSITS.

The Lacepedes is a small group of islands situated upon the North-West Coast about 30 miles to the westward of Beagle Bay, Long. 122deg. E. and Lat. 17deg. S.

It is not known what led to the discovery of these guano deposits, but it is probably due to the whalers who at one time frequented this coast. These would probably visit the islands in order to boil blubber and obtain water and fuel supplies, so as not to be troubled with the natives on the mainland; and it is possible in the event of an unsuccessful fishing season that they would load up a cargo of guano.

Somewhere about the beginning of 1876 the Government became aware that a regular export trade of considerable dimensions was being carried on; they therefore despatched Messrs. Geddes and Roberts to the scene of action with authority to seize any ships removing guano without license.

At the time of their arrival the "Forcade la Roquette" happened to be taking in a cargo upon behalf of a Mr. Lord, an American citizen, residing in Melbourne; they therefore seized the vessel and conveyed it to Fremantle. Mr. Lord then placed the matter in the hands of the American Consul, who made a claim for compensation from the Government on the grounds that the Governor had no jurisdiction over the Lacepede Islands, as they were not included in his commission. However, after certified copies of the map attached to the Commission were forwarded to the Consul no further action was taken.[1] As the result of this experience the Government decided to appoint a resident Commissioner, in which capacity Mr. Richard Wynne was despatched. Upon his arrival his first duty was to make a detailed survey of the islands and to estimate the extent of the remaining deposits, which he put down as 60,000 tons distributed as follows:—5,000 tons on the easternmost island, 40,000 tons on the main island, and 15,000 on the westernmost island. Upon receipt of this report the Government decided to make a charge of a royalty of 10s. per ton on ship's register, calculated upon a basis of 40 cubic feet; this it was estimated would really only equal 7s. 6d. per ton.

The royalty on this basis during the first year of supervision yielded a revenue amounting to £1,242. In the following year this increased to £6,898, and would have considerably exceeded this amount had not an unforeseen disaster occurred through the visitation of a "Willy Willy" (cyclonic storm), which wrecked six vessels while engaged in loading, and caused the loss of six lives, while in the following year £9,721 was paid.

In 1878 the Government decided that it would be far more satisfactory and economical to grant a lease of the sole rights to remove the guano to one firm, who would then be able to build a jetty and lay down a tram line, which would greatly fa process of loading, which had up to this time been car means of boats.

---

[1] Parliamentary Papers, 1876.

With this object tenders for the removal of 40,000 called for on a royalty basis of not less than 10s. per to register, while a deposit of £2,000 was to be lodged wit ernment until the completion of the contract.[1]

The successful tenderers were Messrs. Mockford, M Co., who despatched vessels from Melbourne laden with t plant and material to commence operations, but after landed and erected the discovery was made that the d been completely worked out; therefore nothing remained mantle their plant and re-embark.

Messrs. Mockford, McDonald & Co. then instituted p against the Government, the claim assuming the characte tition of Right, and was for about £40,000. The matter, ing on for a number of years (1882 to 1888), was eventual on for trial before a special jury on the 3rd August, 188 jury's verdict was considered inadequate by the applican Nisi was obtained to show cause why the verdict should aside and for a new trial on the grounds of the inadequ damages and the perversity of the Judge's directions; b plication to make the rule was allowed to lapse. On 1888, the sum of £9,783 6s. 11d. was paid over by the G in full settlement of all claims for damages and costs.

It seems incomprehensible how it came about that te invited for the removal of 40,000 tons when the deposit cally worked out; but looking carefully into the matter on come to the conclusion that the original estimate was fo faulty basis, while allowance was not subsequently ma fact that the 37,226 tons removed were calculated upon feet to the ton basis, which in reality represented 49,634 only leaving 7,000 tons upon a 40 cubic feet basis, pres Mr. Wynne's original estimate of 60,000 tons was a corre also difficult to understand how it was that Mr. Wynne, on the islands, did not point out to the Government that t were practically exhausted before allowing them to a contract.

The Government record a total of £18,611 in royaltie working of this deposit, but since they had to pay Moc Donald & Co. £9,783 besides their own costs and genera with regard to the management of the islands, it will be the revenue was not seriously benefited from this source

There is absolutely no record of the grade of this m since the average value placed upon that exported was £ it must have been of very good quality.

---

[1] Parliamentary Paper, No. 14, 1878.

In 1890 three applications were lodged with the Government for a lease of the Lacepede Islands covering the sole right to remove guano for a period of five years, the lessee to pay a royalty of 10s. per ton on ship's register and to ship not less than 1,000 tons per annum. The applicants were Messrs. Beaver & Co., of Melbourne, who had been carrying on a trade in guano from this coast for several years; Messrs. J. & W. Bateman, of Fremantle, who had been working deposits upon Barrow and other islands; and Messrs. Broadhurst & McNeil, of Geraldton and London, who had been leasing the Abrolhos Islands for a number of years.

This latter firm secured the lease and deposited £250 with the Government, but owing to the unfortunate loss of the "Electra" at Dongara they were unable to ship the quantity agreed during the year. Early in 1891 Mr. F. C. Broadhurst visited these islands and reported as follows:—

> "We regret to say that after a prolonged examination we find them (guano deposits on the islands) all but worthless. On the portion marked green on your plan of Middle Island, there are some small quantities of high-class phosphate, but the total of this could not exceed some few score tons. The whole of the parts coloured yellow on Middle Island are either plain sea sand or else guano so much interspersed with shelly sand as to render it valueless, or very nearly so. Of this yellow portion we took 22 fair samples representative of its whole area, the highest analysis of which but reached 43·66 per cent. of phosphate of lime, and the carbonate of lime is excessive (a fatal objection). As regards West Island, there are a few hundred of tons on this, but thickly mixed with small coral, which renders it of no commercial value also. We also examined the two smaller islands of the group, and they are sea sand. We must therefore abandon the Island."

The deposit of £250 was therefore forfeited.

It seems strange that people, on both this and the previous occasion, should have been anxious to obtain a lease of these islands and to lodge a deposit before making an inspection.

PHOSPHATIC DEPOSITS OF THE HOUTMAN'S ABROLHOS.

This group of islands lies off the west coast, about 50 miles from Geraldton, between Long. 113deg. and 114deg. E., and Lat. 28deg. and 29deg. S. They are disposed in four groups, which taken in order from north to south are named the North, Wallabi, Eastern, and Pelsart Groups.

They were discovered by the Dutch East Indiamen, who, when sailing from the Cape of Good Hope to Java upon the Great Circle system of navigation, picked up the coast somewhere about this latitude; consequently this group of low-lying islands, many being little more than reefs, were a constant source of danger if encountered after dark or in hazy weather.

As in the case of the other islands there is no record relative to the discovery of these guano deposits, but since they do not appear to have been worked until those on the other islands farther up the coast were exhausted, the natural inference is were not of such a high value.

The first shipment of which there is any record was in 1878; but the deposits do not appear to have been reg systematically worked until Messrs. Broadhurst and I tained a lease of these islands in 1885.

Through lack of experience they shipped several carg only yielded from 30 to 40 per cent. tri-calcic phosph quently becoming financially involved, their business was by Messrs. J. & W. Bateman for a period of three yea 1888, during which time 5,900 tons (40 cubic feet), valued a ton, were shipped to Europe, most going to Hamburg, tion to Antwerp. The conditions were at first that t should not contain less than 70 per cent. of tri-calcic but this was subsequently reduced to 68 per cent. It is that this was used in the manufacture of superphospha was stipulated that the material should not contain more cent. of iron; a reduction in price was also made if muc was present, while no increased value was allowed for wat soluble phosphates. The price was 1s. 3d. per unit o determined after boiling in concentrated nitric acid for 1

Shortly after this date the lease of these islands over by Mr. F. C. Broadhurst, who worked them continu 1904, from which date the export of phosphates was pro

In the year 1897 Mr. W. Saville Kent, who had bee in this State reporting upon the fisheries, in a book c Naturalist in Australia," gave the following descriptio islands:—

> "With the exception of the Wallaby Group, which contai rocks [1] corresponding in character with those of the mainland, an elevation of some thirty or forty feet, the largest residue is entir formation, while reefs of considerable extent also encircle the Wa Their composition, as manifested, more particularly in the islands of and Pelsart Groups, consist of hard coral limestone conglomerate, and weathered on its exposed aspects into low over-hanging cliffs a tories, often of the most fantastic shape, which frequently show in their eroded surfaces but slightly altered corolla of the Madr which they are principally composed . . . . From time i as testified to by deep guano deposits, Houtman's Abrolhos has be or breeding centre of countless hosts of sea birds, which still reso enormous quantities in the breeding season . . . . . . On the vast accumulation of guano resulting from the sea birds hav made the Abrolhos their head-quarters, this island group possesses able commercial value."

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[1] This statement was apparently made upon hear-say evidence, since it do from the full text of his work that Mr. Kent visited this group. This point w Prof. W. J. Dakin, D.Sc., etc. Director of the Percy Sladen Expedition to the Ab who makes the following statement :—" It is difficult to understand what p Kent refers to, but in any case his statement appears to be incorrect. We s such rocks on the Wallaby Islands, and it seems unlikely that in the numerous t across them such rocks could have escaped our notice."

In August, 1897, Mr. Surveyor Wells was despatched from Geraldton to the Abrolhos Islands for the purpose of officially estimating the quantity of guano still available on the ground.[1] This officer visited ten islands of the Eastern group and on four of them, viz., Rat, Third, Beacon, and Wooded Islands, found guano, varying from four inches to 27 inches in thickness, extending over an area of 11.72 acres; this he estimated at 13,944 tons, samples of which averaged 57.43 per cent. of tri-calcic phosphate. Of the fourteen islands of the Pelsart Group, nine were found to contain guano, viz. Pelsart, Gun, and seven small islands adjacent. The deposit varied from 7 to 13 inches in thickness over an area of 59.37 acres, and was estimated at 48,468 tons, and averaged 63.47 per cent. of tri-calcic phosphate.

Of the Wallaby Group, 18 islands were examined, but only four, namely West Wallaby, Pelican, North and South Pigeon Islands, contained guano, from about 4 to 17 inches in thickness, over an area of 34.75 acres, estimated at 38,088 tons, averaging 57.42 per cent. of tri-calcic phosphate. Many of the smaller islands also contained a limited amount, but not in sufficient quantity to be worth surveying.

While engaged upon this work he took 23 samples. One-half of each was sent to Mr. John Hughes, of London, and the other half to Mr. S. S. Dougall, the Chemist to the Agricultural Department. These samples, Mr. Wells states, were taken in accordance with the Chemist's instructions, but judging from the results it does not seem possible that the division of the samples could have been properly made, otherwise there would not have been such a considerable discrepancy in the phosphate of lime.

The average of the 23 samples is as follows:—

	Sand.	Moisture.	Phosphate of Lime.
Hughes ..	2.43	7.62	56.20
Dougall ..	2.82	6.16	62.65

Later on 17 samples were analysed by the Government Analyst, as follows:—

Sand.	Moisture.	Phosphate of Lime.
2.59 ..	5.85 ..	61.34

Mr. Hughes reports as follows:—

"You will observe there is a considerable variation in the composition, the percentage of phosphate of lime varying from 46·28 in No. 19 to 72·14 per cent. in No. 11, while the carbonate of lime varies from 2·04 in No. 20 to 10·79 in No. 16."

The agricultural value of Abrolhos guano is now well recognised, and depends upon its richness in phosphate of lime, which, though not soluble in water, is, I find, gradually dissolved by vegetable acids, such as citric acid; consesequently on rich vegetable or peaty soils this guano can be used as it is with advantage as manure for root crops, also upon grass land deficient in lime, and where the quality of the herbage is coarse and rank, and therefore not at present of much use either, for cattle.

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[1] Parliamentary Paper, A.7, 1897.

The effect of this guano on such grass land will be found very be as it will improve and increase the growth of the fine grasses.

As regards the white sample, marked gypsum, No. 18, I am of that this is a specially valuable deposit, containing nearly a quarte total phosphate of lime in a form readily soluble in water, and I hav fore, specially indicated this fact in the analysis, as follows :—

Water (lost at 212°F)	16·03
Organic Matter and Combined Water	17·30
Phosphoric Acid, Water Soluble	5·20
Phosphoric Acid, insoluble in water	20·75
Lime	29·93
Sulphuric Acid	6·22
Alkalies, Magnesia	4·37
Sand	·15
	100·00

Equal to soluble Phosphate 11·35 and insoluble Phosphate 45·3

In 1903 an agreement was entered into between Mr. Broadhurst and the Government, whereby the former was to the latter with 2,000 to 3,500 tons of guano per annum for a of five years, the standard of which was to be not inferior following analysis:—

Water (lost at 212deg. F.)	9.60
Organic matter and combined water	18.80
Phosphoric Oxide	26.65
Lime	34.66
Carbonic Oxide	1.10
Oxide of Iron, Alumina, Alkaline Magnesia	7.73
Sand	1.46
	100.00

Equal to Phosphate of Lime 58.17 per cent., and not to
Carbonate of Lime 2.50 per cent.

This agreement was never carried out, as Mr. Broadhurs going more closely into the mattter, found that he could not this quantity of a higher standard than 50 per cent. of ph of lime.

After 1904 the export of phosphates was prohibited, whe many attempts to get it revoked, Mr. Broadhurst forfeited h to the islands, which was then taken on by Messrs. Fallowfield of Geraldton, upon a royalty basis of 10s. per ton on ship's for each 40 cubic feet raised.

An analysis published in the *Journal of Agriculture* (Australia) in March, 1907, gives the following:—

	Per cent
Nitrogen	1.06
P_2O_5 Citrate soluble	4.57
P_2O_5 Acid soluble	22.38

Equal to 58.8 per cent. phosphate of lime.

In 1916, however, this guano was sold with a guarantee of—

	Per cent.
Nitrogen	0.75
P_2O_5 Citrate soluble	5.00
P_2O_5 Acid soluble	14.00

Or equal to 41.5 per cent. phosphate of lime.

PHOSPHATIC DEPOSITS OF THE RECHERCHE ARCHIPELAGO.

This archipelago consists of a scattered belt of islands which fringe the south coast between Fanny's Cove and Israelite Bay, or more precisely between 121deg. 30min. and 124deg. 10min. E. Long.

It is unknown at what date the first discovery of these phosphatic deposits was made, but the attention of the Government appears to have been directed to them by Captain James Sale in 1904, when he forwarded four samples for analysis. This work was carried out in the Survey Laboratory and showed a result of 80.80, 68.86, 78.78, and 85.40 per cent. of tri-calcic phosphate, and with only about .25 per cent. of sand. Seven samples sent in at a later date assayed only 17 per cent. of tri-calcic phosphate and 9.5 per cent. of sand; while the two highest samples collected by the present writer, out of a large number only yielded 59.37, and 73.50 per cent. of tricalcic phosphate, and 23.50 per cent. of insoluble matter. It is therefore very apparent that the first four samples did not come from these islands, being most probably foreign samples used for comparison and forwarded for analysis in error.

The great advancement made in this State in agriculture during recent years created so large a demand for phosphatic fertilisers that rock phosphates were eagerly sought after, which fact, coupled with the discovery of a fine deposit of this character in South Australia, caused Mr. Chaplin, who was Director of Agriculture in 1907, to form a syndicate, who obtained the exclusive right to prospect the islands of this archipelago for a certain period, at the expiration of which they would have the first right of selection. After Mr. Chaplin severed his connection with the Government he superintended this work in person, but owing to the loss of their boat and plant, due to a severe storm, and there being no more capital available, the syndicate applied for and obtained financial assistance from the Government. Mr. Chaplin then abandoned the management, but prospecting was continued for about 12 months on the various islands, and when a final selection was made of Christmas Island, one of the Eastern Group, situated about 20 miles off the coast near Israelite Bay, in the early part of 1908 the present writer was instructed by the Government to make an exhaustive examination and survey, the full report of which appeared in the Annual Departmental Report for that year.

Christmas Island is about one mile in length, while in width it varies from half a mile at the ends to one quarter of a mile in the centre. The fundamental rock is granite, two bare barren of which (one at either end) rise to an elevation of 500 feet the centre portion, which is about 100 feet above the sea-le covered by a deposit of phosphate of lime and sand vary thickness from a few inches to 15 feet, the average thickness two feet of sand covering two feet of phosphate rock.

Thirty-eight trial holes have been sunk upon this area. were carefully sampled and yielded an average value of 27 pe of tri-calcic phosphate and proved the existence of 102,400 yards. The sampling was done by making a cut down each four sides of these pits, the broken-down material being co on a sampling sheet. This was then roughly sifted to excluc portion of the sand that could be removed by screening, after the sample was broken down, mixed, and quartered until suffi reduced, when it was bagged and sealed.

This mode of sampling was adopted, as it was considere it would most nearly approach that of the actual working deposit, but it may be mentioned that had it been so desirec ples of a much higher grade could have been obtained by out the solid stone quite free from sand; two samples taken manner yielded 59.37 and 73.50 per cent. of tri-calcic phosp

A number of the other islands carry similar deposits, bu have not so far been extensively prospected.

The high-grade portions of these deposits are not suffi extensive to be remuneratively worked with the object of facturing superphosphate, since higher grade rock can be cheaply imported, but there is not the slightest doubt but th will eventually be utilised for application as raw ground phates.

PHOSPHATE DEPOSITS AT DANDARRAGAN.

Dandarragan is situated about 20 miles to the westw Moora, which town is on the Midland Railway line 108 miles of Perth.

This deposit appears to have first attracted notice in when the greenish appearance of the ferruginous rock was mi for an indication of copper, but which upon examination pro be due to the presence of dufrenite, an iron phosphate.

Subsequent investigation by Mr. W. D. Campbell, As Geologist, revealed the fact that the phosphatising of the san was due to the presence of coprolite beds,[1] which he found bedded with ferruginous sandstones and chalk for a distance miles.

The weathered surface of this rock upon sampling pro contain from 0.54 to 2.10 per cent. of phosphoric oxide, the and coprolite beds from 15.32 to 39.34 per cent., and the ferru sandstones, which consisted largely of dufrenite and vivianite, 7.25 to 15.13 per cent.

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[1] Except for a single shark's tooth, the supposed bones of these beds have proved by the Mineralogist and Chemist to be fragments of phospha wood. *Vide* Journ. Nat. Hist. Soc. W.A. IV.

The coprolite beds average something like three feet in thickness, and the underlying ferruginous sandstone, which has been more or less phosphatised, is at least seven feet in thickness.

The primary forms in which the phosphorus occurred in the beds were probably the calcium phosphates of raw or digested bones. These have to some extent been carried in solution by rain water into the underlying ferruginous sandstones, where they have interacted with the iron oxides producing the more stable iron phosphate, dufrenite.

A full report on this deposit, with a map, will be found in Bulletin No. 26 (*q.v.*).

Mr. H. Rowley, analytical chemist, of Perth, who has been identified with this deposit ever since its discovery, has for some time past been conducting a series of experiments with the object of rendering the phosphate of iron and alumina cheaply water or citric soluble.

CAVE DEPOSITS.

In the numerous caves which occur in the coastal limestone hills between Perth and Geraldton there are often extensive deposits of guano resulting from the excrement of birds, bats, and beasts which inhabit them. These are often of high quality since, besides phosphate, they often contain a large percentage of organic nitrates which are readily assimilated by plant life. This material, therefore, produces the most surprising results upon vegetation, but since the deposits are very limited in extent they are only of value locally. In many caverns in other portions of the State, limited quantities of phosphatic material are met with, but these are too small and too far from the market to be of any commercial value. A full report upon some of these caverns will be seen in the Annual Report for 1907, and in Bulletin No. 48 (*q.v.*).

MINERAL PHOSPHATES.

The only form in which a mineral phosphate has been found in any quantity in this State is as Amblygonite, which occurs near Coolgardie, but so far this mineral, which is a fluophosphate of aluminium and lithium, has not yet been found in sufficient quantities to warrant exploitation on a commercial scale. A full report on this subject will be found in the Annual Report of the Department of Mines for the year 1911.

GENERAL.

From the above-mentioned details, it will be gathered that the majority of the Phosphate Deposits of this State consist of the phosphatised limestone, due to the excreta of sea-birds upon the rock surfaces.

These, particularly upon the north-west coastal islands, were of considerable extent and of high quality, but since they were removed prior to their value being recognised by the local farmer, the bulk of that which now remains is too low in phosphates to be of use for the manufacture of superphosphate. Could this, however, be supplied to the farmer for use upon peaty soils in the wet areas in a sufficiently finely divided state and at a low price, it would be of far greater permanent value than the continuous application of acid phosphate, which, being strongly acid, by its continuous use causes the soil to deteriorate, unless an abundance of carbonate of lime is present to counteract the acidity and fix the phosphorus. A great loss of phosphoric acid is also experienced after the application of "super" in a humid climate where the soil is deficient in carbonate of lime either by the leaching of the water soluble phosphates, or their conversion into insoluble phosphates of iron and alumina; while the excess of free sulphuric acid present in this class of manure acts as a solvent of any small quantities of carbonate of lime and magnesia, or phosphate of lime that may be present in the soil, thus allowing the latter to be in part leached or be transformed into insoluble phosphates. If, therefore, acid phosphates are continually applied to this class of land, the whole of the carbonate of lime present in the soil will be converted into sulphate (gypsum), thereby destroying the only substances which have the power to retain the phosphorus in the soil in a form in which it is available for plant food, thus in time rendering it more acid and deficient in phosphate than prior to the application.

Upon the other hand, if phosphorus in the tri-calcic form is applied, this, if in a finely divided state, is slowly liberated by the action of organic acids generated in the soil, but the quantity so rendered soluble is little liable to be leached, since it is only liberated as required by the vegetation; therefore, if added in this form in larger quantities than are required by the crop, the land will gradually be enriched in this element. As all phosphate rock contains small quantities of carbonate of lime, applications in this form also act as a neutraliser of soil acid.

The objection to the use of rock phosphate is, of course, its much slower action, it taking as much as five years to obtain the maximum result unless large quantities of organic matter are present; this, of course, means waiting, whilst the money expended is not yielding its full return; therefore this method can only be adopted at the present high price by those farmers whose means are adequate. If, however, it is desired that a crop shall be immediately taken off the land so treated, this can be done by the use of a small quantity of super, which not only supplies phosphorus in a water soluble form, but also renders a portion of that contained in the ground rock immediately available also.

PRODUCTION OF GUANO IN WESTERN AUSTRALIA (1847-1904).

Year.	Guano Raised. *		Used locally. *	Exported. *		Revenue Collected. *			Exported. †		Value.		
	tons.	cwts.	tons.	tons.	cwts.	£	s.	d.	tons	cwts.	£	s.	d.
1847	..		..	..		..			3		† 18	0	0
1855	..		..	..		..			25		125	0	0
1865	..		..	..		..			35		175	0	0
1872	..		..	..		..			52		107	0	0
1876	2,537		..	2,537		1,437	10	0	735		367	10	0
1877	15,054		..	15,054		7,752	6	8	1,212		6,060	0	0
1878	22,676		..	22,676		14,020	19	7	13,129		66,095	0	0
1879	8,602		..	8,602		2,562	12	3	12,041		54,184	0	0
1880	..		..	..		208	15	0	1,330		6,650	0	0
1881	..		..	..		278	15	0	..		..		
1882	2,690		..	2,690		194	0	0	..		..		
1883	724		..	724		520	0	0	456		2,964	0	0
1884	3,683		18	3,665		2,287	7	9	1,163		7,559	10	0
1885	922		233	689		312	4	4	528		3,432	0	0
1886	10,072		100	9,972		2,697	16	4	10,157	10	66,023	15	0
1887	3,360		229	3,131		2,035	3	0	3,158		20,527	0	0
1888	3,586		449	3,137		1,851	11	0	3,110		12,440	0	0
1889	3,583		188	3,395		1,697	10	0	3,395		8,488	0	0
1890	4,038		125	3,913		1,956	10	0	3 913		9,783	0	0
1891	6,225		508	5,717		2,858	10	0	6,251		15,628	0	0
1892	2,569		777	1,792		1,355	13	4	2,508		4,389	0	0
1893	3,297		157	3,140		1,579	0	0	4,030		7,052	0	0
1894	2,736		218	2,518		969	10	0	2,239		3,919	0	0
1895	1,459		356	1,103		544	0	0	100		200	0	0
1896	1,618		1,168	450		191	5	0	1,660		4,506	0	0
1897	1,897		1,205	692		335	11	6	1,496	5	3,250	0	0
1898	3,604		857	2,747		1,278	4	11	3,950		9,386	0	0
1899	3,092		542	2,550		1,236	5	1	2,015	10	5,165	0	0
1900	1,103		300	803		1,094	8	0	2,902		7,527	0	0
1901	1,692	4	595	1,097	4	466	4	9	1,099		2,742	0	0
1902	1,930		1,130	800		914	2	0	2,400		4,800	0	0
1903	2,668		1,568	1,100		425	19	4	952		2,034	0	0
1904	2,848		1,437	1,411		705	10	0	1,411		4,636	0	0
Total	**118,530**	**4**	**12,160**	**105,754**	**4**	**53,658**	**4**	**10**	**87,486**	**5**	**338,732**	**15**	**0**

***. Information obtained from Annual Reports and Files of Lands and Surveys Department.** **† Information from Statistical Review.**

After the year 1904 the exportation of guano was prohibited; the following table, showing the production of guano since that date which has been locally consumed, is taken from figures supplied in the Statistical Register:—

PRODUCTION OF GUANO, 1905-1916.

Year.	Quantity.	Value.
	Tons.	£
1905-1906	532	..
1907	2,015	6,045
1908	2,009	4,932
1909	1,700	3,500
1910	950	2,375
1911	1,853	4,724
1912	1,282	3,205
1913	1,720	3,440
1914	1,583	3,957
1915	353	1,069
Total	**13,997**	**£32,247**

One shilling per ton was paid upon this by way of royalty.

The shipments which took place prior to 1883 would appear, as far as can be ascertained, to have gone to the United States of America, but subsequently to that date when Messrs. J. & W. Bateman took over the business of Messrs. Broadhurst & McNeil, the bulk appears to have been sent to Hamburg and Antwerp. It is only since 1901 that an official record has been kept of the destination to which guano was despatched, which is as follows:—

TABLE SHOWING THE DESTINATION OF GUANO EXPORTED, 1901-1903.

Year.	Country.	Quantity.	Value.
		Tons.	£
1901 ..	United Kingdom	60	150
	Victoria	728	1,820
	Tasmania	311	772
1902 ..	Victoria	1,600	3,200
	New Zealand	800	1,600
1903 ..	Tasmania	142	353
	New Zealand	810	1,681

LOCALITIES FROM WHICH GUANO HAS BEEN OBTAINED.

Locality.	Period.	Tonnage.	Royalty and Rent.		
			£	s.	d.
Jones, Lesueur & Stewart Islands and Black Hawk Reef ..	1884	2,577	1,675	0	0
Browse Island	1876-1886	23,177	3,158	0	0
Lacepede Islands	1876-1879	37,226	18,611	0	0
Bedout Island	1877-1882	69	38	0	0
Turtle Island	1880-1882	*	3	0	0
East Forestier	1882	*	1	0	0
Dampier Archipelago	1880-1882	*	250	0	0
Barrow Island	1880-1881	*	100	0	0
Montebello Island	1880-1881	*	30	0	0
Trimouille and Hermite	1882	*	15	0	0
Beagle Island	1877	30	15	0	0
Bernier Island	1882	*	15	0	0
Dorrie Island	1882	*	8	0	0
Dirk Hartog Island	1880-1882	*	105	0	0
Faure Island	1880-1882	*	6	0	0
Salutation Island	1882	*	2	0	0
Augustus Island	1881-1882	*	37	10	0
Abrolhos Island	1883-1915	56,025	†		
Carnac Island	1880	*	5	0	0
Undefined Islands	1876-1878	868	483	0	0

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* No returns of tonnage raised, as it was consumed locally.

† The tonnage is only approximate, while Royalty and Rent has not been computed as a whole.

Year.	Bone Dust.		Rock Phosphate.		Superphosphate.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	tons, cwt.	£	tons. cwt.	£	tons cwt.	£
1905	2,218 9	11,286	..	..	8,479 18	21,178
1906	3,369 15	17,629	..	..	8,629 15	20,475
1907	2,569 16	13,946	..	..	9,479 17	30,689
1908	2,259 8	12,264	..	..	15,009 13	50,344
1909	2,833 17	15,260	..	..	14,124 19	50,820
1910	2,966 8	15,786	13,200 0	29,920	19,191 13	100,221
1911	1,585 0	9,106	20,823 9	42,238	15,825 3	49,553
1912	2,850 19	16,871	23,367 0	45,977	8,290 10	25,291
1913	2,405 7	14,930	15,256 18	30,713	856 12	3,255
Six months ending June.						
1914	869 14	5,661	27,970 5	60,711	4,208 2	14,533
1914–15	1,761 2	10,607	24,895 14	54,563	14,015 19	48,940
1915–16	1,976 18	11,502	38,465 10	98,543	..	..
Total	**27,666 13**	**154,848**	**163,978 16**	**362,665**	**181,112 1**	**415,299**

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ACT AND REGULATIONS GOVERNING THE WORKING O DEPOSITS.

Special Leases.

Section one hundred and fifty-two of the Land Act of 1898 as the Land Act Amendment Acts of 1902 and 1906.

On receiving applications in the form or to the effect of the Tw Schedule, the Governor may grant leases of any Crown Lands f not exceeding (except in the case of leases for guano or other ma the collection and manufacture of salt) twenty-five acres, for a t ceeding twenty-one years from the date thereof, at a yearly rental than two pounds and a payment by the lessee of the cost of sur of the following purposes (that is to say):—

(1.) For obtaining and removing therefrom guano or ot

……………………………………………………………………

> Provided that in all cases where it is proposed to grant a longer term than ten years, notice of the applicati lease and of the purpose and term for which it is pro granted shall be published in four consecutive ordina of the *Gazette*, the first publication being at least one m the grant of such lease.

Every application under this section shall be accompanied by a moiety of the first year's rent.

Regulations.

His Excellency the Governor in Executive Council has been approve of the following Regulations respecting the removal of Gu upon Islands or Coasts within the territorial limits of Western Au to repeal all former Regulations.

MINISTER MAY ISSUE LICENSES.

1. The Minister for Lands may, at his discretion, license the Master of vessel to collect and remove guano. The license shall be deemed to be er the Act 40 Victoria, No. IX. (This Act provides Penalties for removing no without license.)

CLASSES AND FORMS OF LICENSES.

2. A license to remove guano shall be either *General, Special,* or *Ex-* *ive*, according to the forms annexed.

GENERAL LICENSE.

3. A *General* License shall apply, save and excepted under these Regu- ons, and all Coasts and Islands within the territorial limits of the State. shall only be issued in exceptional cases, to encourage the discovery and isation of new deposits of guano. Localities comprised within any pre- usly issued *Exclusive* License, or localities which the Minister for Lands y deem it desirable to reserve, shall be exempted from the operation of a *eral* License, and so noted thereon. The localities comprised within any sequently issued *Exclusive* License, but not until the *Exclusive* License been exhibited by the holder thereof, or his agent, to the Master of the sel acting under the *General* License.

SPECIAL LICENSE.

4. A *Special* License shall apply to localities specified and described rein, but shall not exclude the holder of a *General* License, or the holder any other *Special* License, applicable to the same locality.

EXCLUSIVE LICENSE.

5. An *Exclusive* License shall only be issued to the Master of a vessel owners and charterers of which are under special agreement with the Gov- nment to remove the whole of the guano in a particular locality. An *Ex-* *sive* License shall confer the sole right to guano in the locality specified rein.

LICENSES NOT TRANSFERABLE.

6. A license under these Regulations shall not be transferable, and all apply only to the vessel named therein, and the voyage therein referred

GUANO NOT TO BE EXPORTED.

7. Every license shall be for the removal of guano for use in the State, d not for export, and the Minister for Lands may require the licensee to ter into a bond, with one or more sureties, to duly observe this Regulation.

ROYALTY ON GUANO.

8. A Royalty of one shilling per ton, calculated on the registered tonnage the vessel, shall be paid to the Minister for Lands or a duly authorised officer, fore the issue of any license to collect guano, but this charge may, in the se of an *Exclusive* License, be increased by the Governor in Executive uncil.

TERM OF LICENSES NOT TO EXCEED TWELVE MONTHS.

9. Licenses shall be for a period not exceeding 12 months, by the Minister for Lands.

MINISTER MAY IMPOSE FURTHER CONDITIONS.

10. Licenses shall be subject to any special conditions and which the Minister for Lands may deem it proper to endorse there

MINISTER FOR LANDS TO SUPERVISE REMOVAL OF GUA

11. Guano shall be removed under the direction and superv Minister for Lands, or his agent resident upon the spot. The Mi agent may mark off spaces from which only the guano is to be take order accordingly, and shall prevent waste and unprofitable wor deposits.

PENALTIES—REVOCATION OF LICENSE.

12. The holders of licenses and their agents are liable to t specified in Act 40 Victoria, No. IX., in respect of any act not d by the terms of their licenses and these Regulations; and the lic ship infringing the conditions of the license, or of these Regulati order thereunder, shall be held to be revoked or intimation to that to the Master of the ship or his principals by the Minister for L agent.

GOVERNMENT DO NOT GUARANTEE GUANO.

13. The Government will not be responsible for the quantit of any guano licensed to be removed under these Regulations.

QUESTIONS TO BE DECIDED BY GOVERNOR IN EXECUTIVE C

14. Licenses under these Regulations shall be subject to the that any question or matter in dispute arising between the Gove the holder of a license shall be referred for the decision of the Executive Council, and that such decision shall be final and bi both parties.

Under these Regulations 1s. per ton Royalty is charged whil upon which leases are granted is a matter for the Minister's decis case.

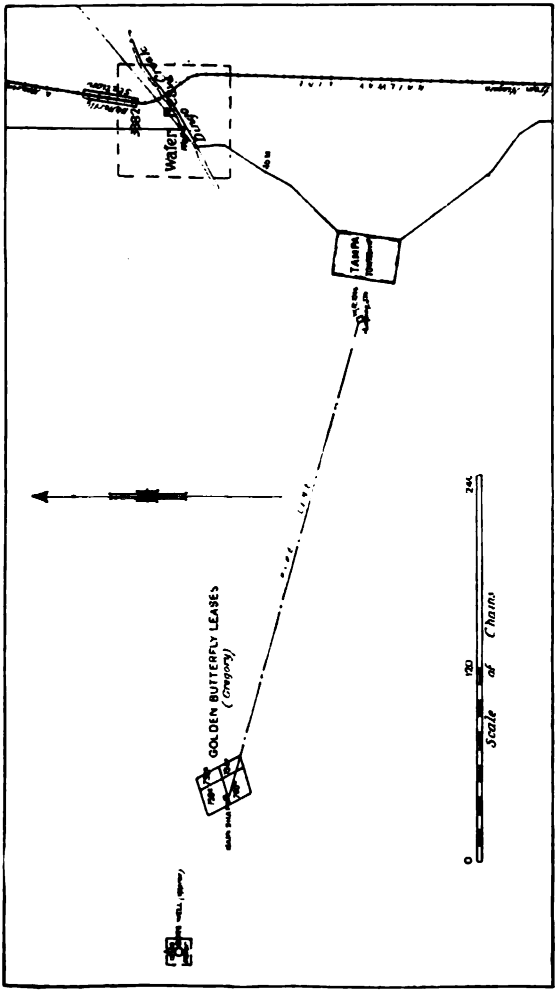
62.—THE GOLDEN BUTTERFLY MINE

UTTERFLY, TAMPA, NORTH COOLGARDIE GOLDFIELD).

By J. T. Jutson.

With Figures 1, 2, 3, and 4, and Two Plates I. and II.

e Golden Butterfly Gold Mine is situated about five miles to t of the Butterfly (late Dingo Creek) railway station, and 4 miles north-west of Kookynie (see locality plan, Fig. 1). roads communicate direct with the mine, the means of com- ion being merely by bush tracks.



Locality Plan of the Golden Butterfly Leases, Tampa, North Coolgardie Goldfield.

The present leases pertaining to the mine are known as the Gregory or Golden Butterfly leases and are numbered 759G, 760G, 753G, and 754G, respectively.

The mine is equipped with a 10-head mill, with grinding pans, filter press and leaching plant, a rock drill plant consisting of two Butterfly rock-drill machines and two stope hammer drills, and the usual winding and other gear.

The mine water is used in the battery, but is not sufficient. (The present discharge is stated to be 1,800 to 2,000 gallons per day.) It is augmented by that brought from the pumping station four miles to the east. The water in the mine is stated to be almost drinkable, being nearly free from mineral matter. No analysis has, however, yet been made of it.

"Mulga" is practically the only timber in the district, so that when "gum" is required it has to be brought from a considerable distance.

The position of the mine is upon a slight rise on the great arid plateau of Western Australia. In the immediate neighbourhood of the mine the rocks are exposed at the surface. They are mostly of a grey colour when undecomposed, fine-grained, homogeneous, and of a basic-looking character. Two fairly fresh specimens have been examined by the Petrologist (see Appendix); one $[\frac{1}{701}]$ from the north drive of the 250ft. level of the mine is referred to a fine-grained slightly quartose diorite, and the other $[\frac{1}{704}]$, from the surface 12 chains east of the mine, is described as a medium-grained diorite with subophitic structure and affinities with plutonic amphibolised dolerites. The main rock of the district may therefore be described as a diorite. It is generally massive, but is schistose in places. A schistose rock from the hanging wall of the lode in the winze below the 300ft. level, south of the main shaft $[\frac{1}{698}]$, has been described by the Petrologist, who considers there is little doubt that it is an altered phase of the more massive rock $[\frac{1}{701}]$, a conclusion towards which the field evidence also points. The strike of the schistosity-planes was noticed in two places on the surface, at one being east and west, and at the other N. 70deg. E. The Butterfly lode strikes about N. 15deg. W., and the quartz reefs noted below strike north-west, west-north-west, and north-east. In the absence of detailed surface examination of a much wider area, it cannot be said that any group of fissures exists having a dominant trend.

A short distance to the south of the mine plant a couple of narrow dykes in the diorite are seen. They consist of a tough. dense, and very fine-grained rock of a felsitic character, but possessing small grains of free quartz. A specimen $[\frac{1}{703}]$ has been determined by the Petrologist (see Appendix) as a fine-grained felsitic quartz pohphyry. To the south and east of the mine some quartz-crop, but with the exception of a pothole on one, no work done on them. Presumably, therefore, they are non-is. Their strikes have been noted above. Laterite is abun-he district. Omitting laterite and other superficial deposits, npanying geological map (Plate I.) shows the geology of s.

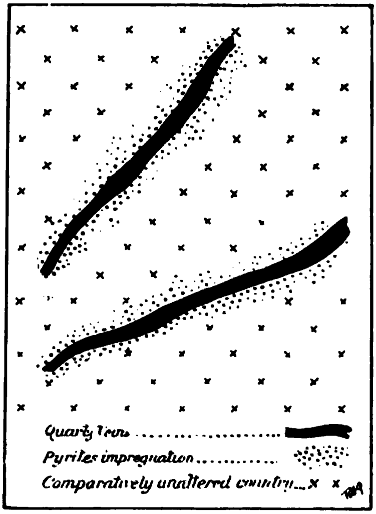
the time of examination the mine workings comprised an and a main underlay shaft sunk for about 350 feet ed on the underlay). There are five main levels, known o. 1 (100 feet), the 150 feet, the No. 2 (200 feet), the 250 l the No. 3 (300 feet), these measurements being all on the . In addition there is a short 50ft. level. The bulk of the has been north of the main shaft. Thus the lengths of the ives are as follow:—No. 1 level about 205 feet, 150ft. level 30 feet, No. 2 level about 270 feet, 250ft. level about 225 d No. 3 level about 50 feet. South of the main shaft the is as follows:—No. 1 level about 118 feet, No. 2 level about , 250ft. level about 97 feet, and No. 3 level about 95 feet. us winzes and rises have been put in, and below the 300ft. addition to the main shaft, there is a winze to the south, s connected with the shaft. The accompanying plans II.) show these underground workings, together with a ction of the lode, the latter necessarily being somewhat dia-tic by reason of the difficulty of obtaining accurate data, stoping, etc.

country consists of diorite similar to that already described e surface. It is comparatively unweathered almost to the but varies a good deal in its hardness, in some cases being oft and easily broken, and in others very tough and dense. s little schistosity, being generally massive, not only on each the lode, but in the horses of mullock in the lode. On ac-f the few crosscuts in the mine little can be seen of the of the country away from the lode. No dykes of any kind en observed in the mine.

lode is of the type described in Western Australia as a mation, that is, it is, in the main, country which has been ed, and into which solutions have been introduced, by means h the original country rock has been largely replaced or ted by silica, pyrites, and gold. The various stages of on of the country can be clearly seen in the lode, the grada-assing from very slight changes in the original country, parts largely impregnated with pyrites, into portions where f the original is left, its place being occupied by quartz, and other minerals (see Appendix ($\frac{1}{699}$). This applies, ulphide ore, the pyrites in the oxidised ore having been de-ed. On each side of some quartz veinlets, the country has

been strongly impregnated with pyrites, while farther a
practically free from this mineral (Fig. 2).

Fig. 2.


Quartz Veins ....
Pyrites impregnation ....
Comparatively unaltered country ... x x

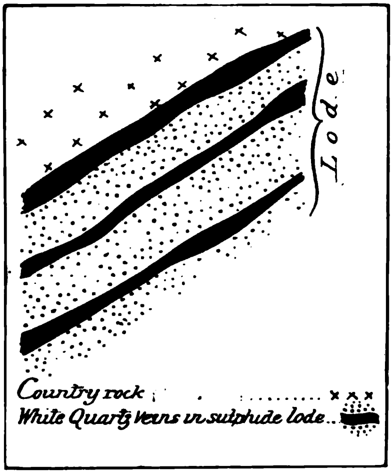
Sketch showing impregnation of country rock by pyrites along quartz veins, Golden Butterfly Mine.

Running through the lode in various directions, but u
the case of the more prominent ones parallel to the gene
of the lode, are numerous quartz veins and veinlets f
sixteenth of an inch to 10 or 12 inches thick. These are,
of white quartz containing little pyrites, and they appear
later origin than the solutions which altered the country in
as there are always sharp junctions between the two, and
quartz veins cut through the ordinary lode (Fig. 3). Th
strengthened by the section disclosed in the winze below t
level, south of the main shaft. Here the original lode a
have been brecciated, and the spaces between the fragment
been filled by the deposition of the white quartz (Fig. 4),
in this case clearly being of later origin than the ordinary
The fragments vary in size from one to 18 inches. Som
small ones are quite rounded, and their sides are in place
embayed, so that it is possible that in addition to the whi
filling the spaces it has also partly replaced some of the
lode; but this at present is merely a suggestion. These whi
veins are regarded by the mine management as of low val
out, however, any separate assays having been made; b
generally have been found to be poor in their vicinity.

In the brecciated portion of the lode just mentioned
white quartz occurs. This is part of the main lode materi

is penetrated by thin veins of the white quartz. Small calcite veins were noticed in one place. No tourmaline has been observed.

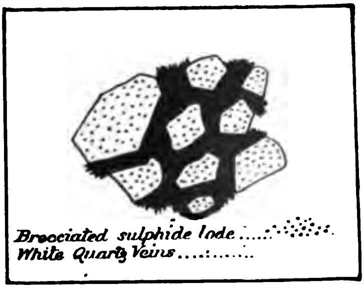
Fig. 3.



Section showing quartz veins in sulphide lode in winze from 300 feet level, South of Main Shaft, Golden Butterfly Mine.

The oxidised ore is usually of a brown colour, is generally rather hard, and is traversed frequently by quartz veins and veinlets. Only in one or two places was the oxidised lode observed to be reduced to a soft white clay, often characteristic of oxidised lode-formations. Pseudomorphs after pyrites occur, and in places these have been

Fig. 4.



Section of sulphide lode in winze from 300 feet level, South of Main Shaft, showing brecciated lode with white quartz veins cementing together, Golden Butterfly Mine.

removed, leaving small cavities, which give the lode mate
cavernous appearance. In portions the apparent rem
replaced mineral constituents of the original country may
Confirmation of the origin of the lode is supplied by m
examination (see $\frac{1}{702}$ of Appendix, which is a specimen
from the north drive of the 250ft. level).

The level of the ground water is about 200 feet on
lay (about 110 feet vertically), but this does not form
line between the oxidised and sulphide ore. Much of
occurs between the 200ft. and 300ft. levels, and althoug
latter level, and down the winze sunk therefrom, sulphid
ably predominates, yet oxidised ore occurs. What little
in the roof of the main shaft below the 300ft. level, of
apparently mostly oxidised ore.

Although the hanging wall is in places rather stron
this cannot be said of the walls as a whole; but an inde
walls is often characteristic of lode-formations by rea
mode of origin of the latter. The ore body, however, i
sharply marked off from the country.

The strike of the lode is about N. 10deg. to 15deg. W
In the different levels it varies from this, sometimes mor
times less to the west of north, but it is usually west of
lode dips flatly to the east, the average dip being bet
and 35deg. The thickness of the lode varies considerabl
difficult to give an average of the whole. Its most con
would probably be about six or eight feet, but it freq
to 10 and 12 feet, and in places becomes reduced to abou
and towards the end of a lens, as at the southern end o
ings, it becomes less than this. On the other hand, wh
as the hanging-wall lode, south of the main shaft, attai
a thickness of about 20 feet.

With the exception of a small branch lode in the
only one lode has so far been discovered north of the
but to the south of such shaft, at least between the 200ft
levels, two lodes occur, which are known as the footwall
wall lodes respectively. (A thin lode to the west of t
lode at the 300ft. level has also been located, but this ne
be considered). The hanging wall lode is the thicker, rea
20 feet in one place, while elsewhere it is of substanti
At the 300ft. level, just south of the main shaft, a lod
15 feet thick. This probably mostly represents the h
lode, but it is possible that the footwall lode is here uni
The footwall lode varies from about four to 12 feet i
The two lodes probably unite well above the 200ft. lev
stated to have done so towards the southern end of th
but their union has not been proved to the north or

although in the latter direction they probably soon combine. The lodes are separated by a horse of mullock, consisting of the usual country, diorite.

Wherever seen at the southern end of the workings, the lode appears to thin out, but the channel seems to remain. Little work has been done in this direction south of the No. 1 rise south.

The lode is continuous along the drives north of the main shaft, but tends to thinness in places. Thus at the 200ft. and 250ft. levels there is for some yards a contraction to two or three feet, the walls consisting of very hard massive diorite, while the lode here is practically merely schistose altered diorite; the mineralising solutions have apparently almost missed this portion. This schistose diorite commences about 60 feet north of the main shaft at the 200ft. level, but farther north at the 250ft. level. If the two portions are joined, the line connecting them pitches to the north at about the same angle as the small shoot farther north, but whether this is anything more than a coincidence cannot at present be said. At the end of the short north drive at the 300ft. level the lode is only about three feet thick.

The main shaft below the 300ft. level has apparently been sunk below most of the lode. The roof shows some lodestuff, and the lode as seen at the 300ft. level, immediately to the south of the main shaft, appears to be rising so as to pass over the main shaft. Down the winze from the 300ft. level, the lode is well exposed. It is largely sulphide ore, and a thickness of six feet can be seen. The hanging wall forms the roof of the winze, but the footwall was not exposed. This winze has been connected with the main shaft, but neither this connection nor the bottoms of the shaft and winze could be seen on account of some water having accumulated there. Here the lode was said to be 11 or 12 feet thick.

The mine, so far as developed, has been largely stoped out. South of the main shaft the lode has been mostly removed between the surface and the 300ft. level. North of the same shaft the open-cut has removed much, and between the 50ft. and 150ft. levels most of the lode has been taken out. Between the 150ft. and 300ft. levels a strip about 30 feet wide, close to the main shaft, has been stoped, and also the northern half of the lode between the 150ft. and 200ft. levels; all these latter remarks apply to the lode north of the main shaft. Very little stoping has been done above and below the 250ft. level from about 50 or 60 feet north of the main shaft.

From the above particulars it will be seen that a shoot occurs practically the full width of the workings near the surface. It splits north of the main shaft at about the 150ft. level, and the northern portion pitches to the north, but appears to die out between the 200ft. and 250ft. levels. The southern portion continues without any distinct pitch to the 300ft. level (below which only a winze and the main shaft have been sunk) between No. 1 rise south and a distance about 30 feet north of the main shaft, the principal portion being between the main shaft and such No. 1 rise south. It is evident that this shoot forms a lens of ore of unfortunately short length horizontally.

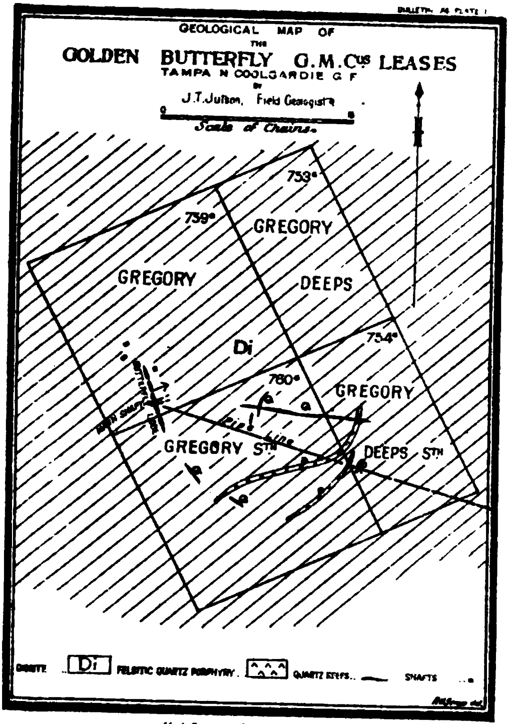
The gold is said to be very fine, and rarely to be seen in the ore. It is stated to be free as far down as the mine has been worked, in the sulphide ore as well as the oxidised. Values appear to have been better nearer the surface than lower down, but in the main shoot this has probably been somewhat compensated for by the increase in thickness of the lode between the 200ft. and 300ft. levels.

Prior to 1912 the leases produced 59.36 fine ounces of gold from 235 tons. The official returns of the company for the years 1912, 1913, and 1914 show a production of 7,808.27 fine ounces from 31,379.32 tons, giving an average return of 0.25 fine ounce per ton. The low-grade character of the ore is clearly indicated.

The mine has been closed down perhaps only temporarily. With regard to its future prospects, the lode channel appears to be strong and well defined, and it should live to a reasonable mining depth. Even where the lode thins and values become poor, as at the north and south ends of the mine, the channel remains; and in the winze below the 300ft. level the hanging wall is smooth and regular. Concerning the lode itself, it is generally found in Western Australia that lode-formations are persistent in depth, and there appears to be no valid reason why this lode should not continue. It is difficult to say anything definite as regards values. The lode is so low-grade that almost any diminution in values would be sufficient to make it unpayable, and there is no criterion that it will increase in value, unless the country in the lode becomes more completely converted into ore, in which case there is a chance of more gold occurring. On the other hand, as the lode is evidently of a lensy character, there is the possibility that another fairly thick lens of ore may occur below the present one; and its thickness may enable it to be worked profitably. The same remark applies to farther south of the main shaft than at present worked. Values appear to give out to the south, and the lode becomes thin, but as already pointed out, the ore channel exists, and it is quite feasible that another ore body will be found in that direction. The 250ft. level north drive has been unprofitable, but ore may exist below it. Again, there is the possibility of the hanging wall lode being found north of the main shaft. The ore body displayed in the winze below the 300ft. level looks very well, although the values are not high (using this term relatively only. Thus "high" values in this mine, say, 50s. or 60s. per ton, might be "low" in others.)

It may be remarked that while it has been demonstrated that the ore body is a low-grade one, it has by no means been proved that it is worked out. The writer is therefore of opinion (assuming

The Hon: R.T. Robinson K.C. M.L.A.
Minister for Mines


GEOLOGICAL MAP OF
THE
GOLDEN BUTTERFLY G.M. Co's LEASES
TAMPA N. COOLGARDIE G.F.
BY
J.T. Jutson, Field Geologist.

H J Pether, Government Lithographer, Perth, W A

there are no difficulties in extraction) that, taking the whole of the circumstances into consideration, a further trial might be given to the mine by the deepening of the main shaft to 400 feet or more. Subsidiary to this an attempt might be made to test the ground farther south than yet opened up, either by driving along the 200ft. or 250ft. levels, or perhaps by a series of bores from the surface. The lode lies so flatly that this latter method could be tried without any great depth of boring being required. It must, however, be borne in mind that in view of the low-grade character of the ore, and the futility of expecting to keep always in payable ore, sufficient capital should be provided to enable developmental work to be kept well ahead.

The question of secondary enrichment has not been considered here, as the data are insufficient. The known facts of the mine are, however, in the writer's opinion, sufficient to justify a further trial.

The writer is informed that there is no difficulty in the extraction of the gold from the sulphide ore, but this does not come within his province.

The assay values of the mine (which have been considered in the preparation of this report) have been supplied by the manager, Mr. G. S. Beresford, to whom thanks are due for the same and for facilities for inspection of the mine.

24th October, 1914.

APPENDIX.

PETROLOGICAL NOTES,

By R. A. Farquharson, Petrologist.

$\frac{1}{703}$ (15 chains E.S.E. of Golden Butterfly Mine).—A minutely grained dark-grey felsitic rock showing frequent small clear crystals of quartz and others of felspar. The margins weather to a greyish-white phase. There are a few cracks or irregular joints in the specimens.

S. Occasional phenocrysts of quartz and felspar appear in a fine-grained ground mass consisting of small plates of felspar and quartz, small ragged rods of felspar and a semi-opaque dust in strings and small patches often surrounding the quartz and felspar plates, and consisting of chloritic micaceous scales. Often the latter is yellowish or yellow-green in colour, associated in places both with muscovite scales, epidotic grains and small grains of calcite. With the yellowish-green patches are small grains of black iron ore and an occasional crystals apparently of rutile. The quartz phenocrysts are remarkably euhedral or truncated at alternate corners; slight resorption is noticeable on the margins of some of them, and cracks occasionally occur. The felspar phenocrysts are square, tabular or columnar, all turbid from kaolinisation and often micacisation, sometimes strongly twinned on the albite law, sometimes almost wholly micacised. Determination of the species, especially of the phenocrysts, is difficult, but the rods and plates in the ground appear to be albite. A peculiar feature of the ground is the occurrence of a number of round radially fibrous felspathic grains resembling spherulites, due to a felspathic intergrowth. These have no definite arrangement, occurring merely scattered amongst the rods and grains of the ground mass. In some cases, rounded felspar forms appear to be partially platy and partially radial, the latter arrangement resembling a fine albite lamellation.

The rock is a fine-grained felsitic *quartz-porphyry*.

$\frac{1}{704}$ (12 chains E. of Golden Butterfly Mine).—A medium grained dark-green hornblende-felspar rock.

S. The chief constituents are hornblende and felspar, with a lesser amount of black iron ore in ragged plates and grains. The hornblende occurs in ragged columnar aggregates, the columns sometimes small and almost prismatic, sometimes large and almost platy. In all cases there is an absence of crystalline outline. The species is green in colour with pleochroism from green to greenish-yellow; incipient chloritisation is not uncommon, resulting in a weakening of birefringence. The aggregates are loose, the intervals being occupied by roughly columnar and platy felspar, in amount almost equal to that of the coloured constituent. The felspar columns and platy columns and plates are generally slightly turbid from kaolinisation—sometimes from slight micacisation; are coarsely twinned, sometimes on the karlsbad, sometimes on the albite law. Some of the plates do not exhibit twinning. In some places there is an interpenetration of several crystals. Cracks are occasionally noticeable as well as a slight bending of the lamellæ. Owing to the paucity of definite albite twins, and the turbidity, determination of the species is difficult, but from such measurements as have been made, the species is in part at least rather acid, the angles agreeing apparently in places with albite (10°/11°). The structure is referred to the sub-ophitic. The felspar has a stronger tendency to crystalline outline than the hornblende, and frequently exhibits a coarse plexal character, with the hornblende partially moulding the forms. The structure resembles that of some coarse dolerites. A little quartz occurs in occasional grains and a few veinlets. Some grains of epidote are observable associated with chlorite or in fine granular form with felspar. The iron ore is fairly common in large ragged plates bluish in incident light, and referred to magnetite (? titaniferous). In some of the plates there is the striated appearance of ilmenite, suggesting that the ore may be a residual product after alteration of augite to chloritised hornblende. Some needles of apatite are present. In the general structure, the rock resembles a coarse dolerite in which the augite has given place to hornblende, though the character of the felspar appears more acid than in dolerite. It is probable, however, that a basic species such as labradorite is present.

The rock is put down as a fresh medium-grained *diorite* with sub-ophitic structure and affinities with plutonic amphibolised dolerites.

$\frac{1}{701}$ (N. drive, 250ft. level, Golden Butterfly Mine).—In hand, rather similar to $\frac{1}{704}$ but of finer grain and somewhat jointed, and with pyrites on the joint surfaces.

S. In general, similar to $\frac{1}{704}$, but the hornblende is in more ragged and more fibrous aggregates and strings; the individual forms of the aggregates are also smaller. The felspar is mostly in ragged platy forms, and exhibits a greater absence of twinning than in $\frac{1}{704}$. Moreover, in many of the felspars, small prisms and scales of greenish chloritic hornblende are enclosed, and minute needles of hornblende penetrate the margin of both the felspar and quartz plates. Small quartz plates are more frequent than in $\frac{1}{704}$. Though there are occasional columnar felspars with partially idiomorphic outline, in general there is little suggestion of ophitic structure; and the ragged nature of the hornblende, the extent to which the felspar plates enclose chloritised hornblende scales and needles, and the rounded platy characters of the felspar give an ill-defined structure to the rock. Apatite needles, iron ore and epidote occur as before. There is little doubt that the rock is a facies of $\frac{1}{704}$, but a facies decidedly more dioritic than $\frac{1}{704}$.

It is referred to as a fine-grained slightly *quartzose diorite.*

$\frac{1}{698}$ (Winze from 300ft. level S. of main shaft; hanging wall of lode).—Dark-green rather weathered sheared greenstone with chloritic sheen on the shear surfaces.

S. Slide consists of numerous chloritic scales and loose scaly aggregates and numerous grains of calcite punctuated by black aggregates of iron ore grains, of which most preserve some remnant of crystal form, all obscuring a basis which is seen to consist of felspar plates and a few irregular quartz plates. The iron ore (magnetite or ilmenite) is in forms suggesting that it is a decomposition product of a pre-existing ferro-magnesian, doubtless augite or hornblende. The calcite grains—mostly very small—are very numerous, associated with minute chlorite scales. The felspar forms are very indefinite, obscured by chlorite scales and carbonate grains as well as sometimes by micaceous scales. Structure is also indefinite—there is some platy columnar structure in the altered felspar, resembling that of $\frac{1}{704}$—but there is little doubt that the rock is an altered phase of $\frac{1}{701}$, sheared and considerably weathered.

$\frac{1}{700}$ (About 300ft. level).—A dark-green rock identica
but traversed by quartz veins, on each side of which th
very heavily charged with pyrites, producing a kind of
of the green rock.

**S. Rock identical with $\frac{1}{698}$; but in proximity to the quart
black iron ore has been converted by sulphide solutions into py
probably the chlorite itself has lost its iron, which has also been co
pyrites.**

$\frac{1}{699}$ (ore from winze from 300ft. level, south of mai

**A phenomenon similar to that in $\frac{1}{700}$ has occurred in the case o
men. Remains of iron ore are still to be seen, but most of the form
partially or wholly converted to pyrites, while the main mass of
occupied by large plates of a carbonate (calcite), and numerous
columnar turbid twinned felspars which are frequently themselv
carbonated. There are occasional bands of quartz and quartz mo**

**The rock in hand is greyish in colour, of medium to fine grain,
white quartz veinlets producing the appearance of banding, and h
tised material between the bands. Since in some cases there is no
of the surrounding material in proximity to the quartz veins, it
that the lode alteration of the rock (carbonation and pyritisation)
prior to the introduction of these veinlets. On the other hand, s
veins are bordered by a heavy deposit of pyrites, so that there n
sets of quartz veinlets in the lode.**

$\frac{1}{702}$ (N. drive, 250ft. level).—A somewhat coarse-gra
much weathered ferruginous rock consisting of blackish ir
crystals separated by yellowish or reddish-white felspar.
a heavily oxidised, iron-stained, coarse amphibolite.

**S. Consists of large turbid columnar and platy crystals of fels
lar platy crystals of quartz, scaly particles of yellowish and greeni
and many irregular platy crystals of bluish-black iron ore, surrounde
stained yellowish or brownish chloritic and felspathic material.
yellow epidote appear; the felspar plates, some of which are t
partly kaolinised, partly micacised. Yellowish scaly chloritic p
streaks are common, but they are mostly iron-stained.**

**The structure is undoubtedly platy as in plutonic rocks but
obscured by alteration.**

There is little doubt, however, that the rock was or
felspar-quartz-hornblende rock, probably identical with
small amount of a kaolinised felspar-quartz intergrowth

63.—GOLD DEPOSIT AT FIELDS' FIND (THE PATCH), DUKETON, MOUNT MARGARET GOLDFIELD,

By C. S. Honman.

(With a Sketch Plan, Plate III.)

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INTRODUCTION.

Field's Find was discovered some three or four years ago, when alluvial gold was first found around a "boody hole." A rush followed, and some rich claims were pegged. Over 1,000 ozs. of alluvial gold was won off the patch, but it is believed that altogether 2,000 ozs. would be nearer the actual figure.

Further prospecting revealed alluvial gold to the north, on rising ground above the original workings. An acre of ground was dry-blown here; subsequently still further north two more alluvial patches of about an acre each were worked. The original workings cover an area of about 12 acres.

On the line of these alluvial patches a number of shafts have been sunk, and some rich patches of gold were obtained here and there, apparently close to a schist footwall and associated with ironstone lodes resting on the supposed footwall. Most of these patches were struck at about 40 feet below the surface.

Altogether between 30 and 40 such patches were obtained, all disconnected, and owing to the decomposed nature of the country apparently occurring anywhere and in all kinds of country, consequently a method of blind stabbing has had to be resorted to. The largest patch yielded 250 ozs. of gold, and others 200 ozs., 170 ozs., 75 ozs., down to 50, 40 and 35 ozs., and as small as 2 ozs.

TOPOGRAPHY.

The find is situated roughly three miles west of Duketo site, and occurs on slightly undulating country. Between and "The Patch" the ground is almost level. To the so there appears to be a fall towards the head of Borodale Cr the north-west the country rises gradually towards Inji Mason Hill. There is rising ground to the south-east. T alluvial workings occur in a depression which falls to the so

GENERAL GEOLOGY.

Owing to the hurried nature of my visit no time was for any geological mapping of the surrounding country, rocks appeared to be composed of decomposed greenston for miles around. Isolated and narrow bands of what app be granite schists were noted here and there, but owing to composed leached nature of the country these might be porphyries which can be definitely recognised a few miles "the Patch."

On the find itself two kinds of rocks are represented

(1) Decomposed schist, probably derived from an A lite schist.

(2) Decomposed massive intrusive, probably deriv a fine-grained Dolerite.

On the west of the intrusive rock the schists are eit acid or very much leached, but at no great distance west ously basic schists occur again.

The schists all strike roughly N. and S., and dip fro to 50deg. to the west. The massive rock is an intrusive dyk across the schist at an acute angle on a bearing of 25de north, and has an average width of about 100 feet. The d to the west at a steep angle varying from almost vertical to

Along the eastern contact of the dyke and the schist a side" or greasy head occurs, with vertical groovings, givi appearance of a contact fault. This is borne out by the b of quartz leaders coming in on to the contact. When th come in from the schists and dip towards the contact they be dragged into the contact, while leaders coming from the also dipping towards the contact are broken short and ap dragged upwards along the contact or greasy head. Leade fault zone are also crushed and granulated. It therefore that the dyke has slipped downward from the footwall country, or the contact is a plane of normal faulting (see tion of figure on plan).

At the surface it is impossible to recognise the existen dyke without scraping off the loam, and then it is extremel to distinguish it from the schist on account of the cement or 20 feet below the surface, owing to the extreme alteration rocks, it is impossible to see the contact, and the schist cannot initely distinguished from the dyke above that depth, except nds of ironstone occuring along the planes of foliation and g with the schists towards the contact.

n the southernmost lease, known as the Gravel Pit, the altera- f the rocks is more extreme. The surface rock here has been changed into a laterite capped with cement, and along the t of the dyke and schist large pockets of ironstone gravel or te) have been formed by the concentration of the ferruginous uents of the rock into nodules. At first sight these pockets vel appear to be of alluvial origin, but they are undoubtedly treme form of alteration of the country rock in the neigh- ood of the contact fault.

long the contact wall the line of the cement which caps the at the surface has been leached out, forming a ruggy channel extends down from the surface for some distance. The y hole" from which the first gold on the find was specked was bly formed by a similar leaching of surface line from the n contact of the dyke.

he quartz leaders in the dyke are short and narrow and more ish veins. They were probably formed by the filling of shrink- racks on the margin of the dyke. These quartz leaders gen- strike north and south and dip 45deg. east, towards the t. The quartz leaders coming in from the footwall side, on her hand, are generally parallel with the contact and dip, the as the schists.

ECONOMIC GEOLOGY.

he occurrence of the gold on the find appears to be btedly associated with a contact fault, which is repre- by the "slickenside" or greasy head that divides the schist the massive greenstone. Patches of gold occur when a quartz from the dyke or massive greenstone abuts against the greasy When a patch occurs the gold impregnates the country about reasy head, and along the course of the leader and on the g-wall side of the head. Leafy gold can also be seen along ce of the greasy head. At the time of my visit no one was y working out a good patch, but Messrs. Brennan, Duke, and were working a couple of small patches, and from these some te could be made of the nature of the gold occurrence.

he quartz leaders in the massive greenstone in most cases N. and S. and dip 45deg. east, and between the leaders and el to them there is a slight incipient foliation. The gold solu- appear to have ascended along the greasy head and to have ted their gold contents in the shrinkage fissures in the massive There are cases in which patches have been found in the massive rock away from the greasy head, but wherever poin they were associated with a quartz leader and were probably the quartz leader from the greasy head.

The quartz leaders are very narrow, and are not cont but occur in small gashes, which may account for the occurr gold in patches and not as a continuous shoot.

Supposing the quartz leaders were continuous, then th of intersection with the greasy head would pitch about 20 deg if the greasy head is taken as striking 25deg. W. of N. and 80deg. west and the leaders as striking N. and S. and dipping to the east. Hence it is probable that along the greasy head of patches may occur pitching to the south at 20deg., but ently with big blank spaces between them. It is possible, h that in places where the patches are fairly close that values w from patch to patch and probably provide lode material betw patches of sufficient value to pay to crush at a battery. W absence of anything else to go on, the contact fault or greas should take the place of an "indicator" to the next patch w last has been worked out.

The contact fault should extend down to a great dep there is no reason why the vertical distribution of the patches be any different from their horizontal distribution at abou level all along the line.

To the east there are some large blows of quartz, the which cannot be discerned on the surface, but which is proba same as the schists. If the blows live to hit the contact th possibility that they may carry gold there.

The greasy head often carries a narrow quartz vein ap connected with leaders coming from the schist wall.

THE LEASES.

The North Block G.M.L. 1937T (Messrs. Dwyer Bros.).— lease six prospecting shafts have been sunk. At the south deepest is down 67 feet in hanging wall country and is sun the water level, which is about 63 feet. At 61 feet, drive and south follow the hanging wall side of the greasy head. feet a patch has been worked east of the shaft.

At the north end of the lease one shaft is down in hangi country, but no gold had been located below the surface. the northern boundary there is a dry-blown patch covering an acre of ground, on which claims yielding 30ozs. of gol worked. The richest gold was got just above the contact f

Just outside the northern boundary on the same alluvia there are three prospecting shafts, one in hanging wall coun two in footwall country.

four chains north of the same boundary there is another blown patch. This has been prospected by sinking six he patch, two in hanging wall country and four in footry. The two countries can be easily distinguished on the t in the neighbourhood of the contact they are very much d it is difficult to locate the contact. No results were rom these underground workings, though some nice reefs sed in the schist dipping towards the contact.

south end of the lease from about 20 feet north of the t a 200-oz. patch was obtained at a depth of 35 feet, and patches south of the water shaft.

. 2018 (Messrs. Dwyer & Macallum).—On this six prosafts have been sunk, three in footwall and three wall country. The party is at present working from in the middle of the lease from where they obtained a the hanging wall country and close to the contact. They riving south on the contact at 50 feet. The kaolin in the ood of where they got a patch shows fine gold distributed

. 1938T (Messrs. Clarke & Cox); now held on tribute by ennan, Duke & Hogan.—This party was working at the of the lease, and had struck two small patches at 40 feet tact fault. One patch contained about 35ozs. The gold around the leader, and fine where it impregnated ironkaolin. They were driving north and south on the con-

south end of this lease a considerable amount of work done, and a patch yielding 250ozs. was obtained here. ck of ground between leader coming in from the south ntact had been worked out. The ground between the der and the contact is apparently gold-bearing. The been worked for 70 feet from the contact.

of where the above leader cuts the contact the dyke apake a slight turn to the east. It is possible that the dyke ractured or slightly twisted, causing the leaders to pene-e opposite side of the dyke and possibly the gold had d across to the western contact and southwards along the ntact. This may account for the poor results obtained pecting the eastern contact in the south block, or Gravel

outh Block, G.M.L. 1917T (Messrs. Field & Fox); locally the Gravel Pit.—A great deal of work has been done all contact at about 40 feet, but with very discouraging rey prospects that have been obtained have been from the ll the workings in this lease are on the alluvial patch, and gold from the alluvial was obtained from 100 to 150 feet e underground workings on the eastern contact. The line

of strike of the richest gold is roughly parallel with t
contact and across the "boody" hole from which the or
was specked. I am of the opinion that in this lease t
contact of the dyke will prove to be the chief gold ca
would suggest prospecting near the "boody" hole, whic
100 feet west of the eastern contact.

Outside the southern boundary there are three shaf
which are sunk in footwall country and the western one
wall country. The contact has been driven on for 100
feet from surface, but without result, but the drive has r
the front all the way. At one place on the contact a seri
were encountered extending from the surface. It is pro
the "boody" hole is the opening of a similar line of vu
western or opposite contact of the dyke.

RECOMMENDATIONS FOR FUTURE PROSPECTING.

The patches have so far all been got at about 40 fee
surface, and in almost all cases the shafts from which
been got have been sunk in footwall country. These s
sunk vertically until the country was sufficiently undeco
give a schist footwall, which, dipping less steeply than t
when sunk on took the shaft up against the contact, and o
a promising looking ironstone lode.

If a patch were struck on the contact the ironston
been regarded as the gold carrier, whereas really it is o
in the schist impregnated with iron, dipping with the
abutting against hanging wall country.

The plane of schist being taken as footwall, a rise pu
the ironstone would lead into footwall country and leave
on which the patches occur at the back of the rise. He
lows that if the contact fault is the true plane of the pa
by following it upwards there should be 40 feet of backs
unprospected.

In sinking there should be no difficulty because th
wall of massive greenstone would be easily recognise
bounded by the greasy head, or zone of greasy heads.
there may be two or three parallel heads and branch
they should never be far from the contact and one (the
gold carrier) will be more distinct than the others.

In rising the difficulty is that the contact fault or g
is not so distinct near the surface, and the rise is apt to
foliation of the schist which goes into the footwall co
most of the ironstone leaders are parallel with the schist

The ironstone in schist has, in my opinion, nothing t
the gold except that the ironstone formations happen to

follow the quartz leaders into the schists. The ironstone formations are merely concentrations of iron due to the leaching of the country, and generally where ironstone is formed large masses of kaolin and pug are left around it.

In Messrs. Clarke and Cox's workings the gold could be seen in both the kaolin or pug and the ironstone, and on either wall of the greasy head.

It is therefore evident that the ironstone and pug is apt to mask the true structure which is responsible for the gold occurrence.

Below 40 feet this alteration, which is due to the action of atmospheric waters, will be less intense and the structure plainer.

The western contact of the dyke has so far not been prospected below the surface, and very little on the surface. This contact should be well worth trying, as the same conditions should occur there except that the dyke instead of the schists will be footwall, and the schists hanging wall. The difficulties on the west side of the dyke will probably be greater, because the schists will be dipping down and away from the contact and will probably carry quartz leaders and ironstone formations, which would be tempting to follow.

The rich alluvial gold from "the Patch" has probably come from the western contact, because the ground around the boody hole does not appear to have been subjected to any water action, since there is only a thin coating of alluvial (a few inches), and any sudden rush of water would have been carried away in the deep ground (two or three feet) on the north and south side of the alluvial workings.

In the deep ground the rich claims were lower down than the western contact, but here, apparently, a sudden rush of water occurred, probably caused by a severe thunderstorm, as I am told that the gold was distributed through the wash from top to bottom.

If the rich gold had come from the eastern contact, the rich alluvial should be very close to that contact, especially as the contact is dipping west.

I would therefore recommend:—

(1) On all leases to follow the contact-fault or "greasy head," using it as an "indicator."

(2) In the northern leases rise up on the contact fault from convenient places in levels driven on the contact.

(3) In south block, sink on as conveniently close to the boody hole as possible, find contact and drive on it.

(4) If on a series of good patches, prospect for further patches as if they were pitching south at 20deg.

SUMMARY.

(1) A fine-grained basic dyke striking 25deg. west o North and dipping 90deg. to 75deg. west, cutting at an across greenstone schists which strike north and strik 40deg. to 50deg. west, occurs.

(2) The gold occurrence is composed of a series of gold associated with quartz veins in shrinkage cracks against a contact fault occurring on the eastern wall of t

(3) The gold is never far from the contact fault ex carried into country by a quartz leader.

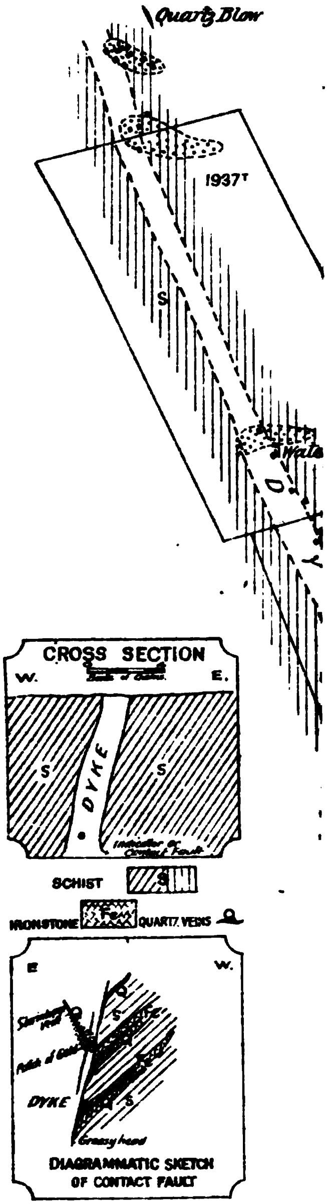
(4) The patches occur mostly in the hanging wall tact fault or indicator.

(5) The contact fault is represented by a greasy he enside which is probably the carrier of the gold solut have impregnated the shrinkage veins in the dyke.

(6) The western contact is probably the chief ore-b at the southern end of the line.

(7) The vertical distribution of the patches should from their horizontal distribution.

8th June, 1916.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Indicator or Contact Fault
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IRONSTONE
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S
Patch of Gold
DYKE
S
Greasy head
DIAGRAMMATIC SKETCH OF CONTACT FAULT

64.—INVESTIGATION INTO THE CAUSE OF THE MINERALISATION OF THE "SEVEN-MILE" SWAMP AT GRASSMERE, NEAR ALBANY, SOUTH-WEST DIVISION.

By H. P. Woodward.

(With a Map, Plate IV.)

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Introductory.

This investigation was undertaken at the request of certain settlers who claim that the drainage as carried out by the Government has not only been ineffective, but has in reality caused considerable damage to their lands by causing the deposition of certain injurious matter upon them, *i.e.*, by the flooding of their lands by storm water brought down from the hills by a drain which is said, contained injurious mineral matter.

Evolution of Topography.

With the object of making the subject of this report as clear as possible, it will be necessary in the first instance to consider the physiographical changes that have taken place in this, and during recent geological times.

The area under review embraces that narrow strip of coastal country which runs in an east and west direction from Princess Royal Harbour, off King George's Sound, to Torbay Inlet.

It consists of a low-lying valley about one and a half miles in width and 10 miles in length, bounded on the south by a coastal range composed of granite masses and ancient consolidated calcaceous sand dunes which rise fairly abruptly from the flats to an elevation of from 500 to 700 feet. On the rock side of the valley the

land rises more gradually, the surface of the slope being
most part covered by sand and iron lateritic gravels with o
outcrops of granite interspersed between small swampy ba

A number of bores have been put down from time to
this valley with the object of proving supposed coal or oil
but in every instance these, after passing through beds
sand, ferruginous sandstones (coffee rock), and in some i
seams of brown coal of poor quality, encountered crystalli
at depths varying from 50 to 150 feet. This proves it to be
granitic trough which at one time probably formed a shallo
connecting King George's Sound with the sea at Torbay.

This strait appears in the course of time to have silted
material brought down by the numerous streams which d
country to the northward, assisted by the direct wash-off
coastal hills to the southward, and to a certain extent by sa
wind-driven over these hills.

This latter is evidenced by a series of sand ridges which
the valley at right angles, thus cutting it up into the
swamp basins of which it is now composed.

This ancient strait is now represented by a series of s
inlets, freshwater lakes or lagoons, and swamps which com
the eastern end with Princess Royal Harbour which is a
tively shallow inlet open to King George's Sound. Into t
the swampy country for a distance of three miles to the
and known as the Robinson Estate is drained, no engineer
culty being experienced owing to the fact that the distan
significant and the elevation of the surface sufficiently ab
water to obtain a fair fall in the drains. Upon the western
this area the main valley is crossed by the largest of the sa
before referred to, which forms the divide or water parting
it and the low-lying area to the westward in which, still tak
in the order from east to west, lies the "Six Mile" swamp,
again divided from the "Seven Mile" swamp by a sand s

The "Six Mile" swamp, besides the run off from the s
ing hills and numerous springs at the base of the coas
originally received the water brought down by the "Six Mil
and, when filled, overflowed at the lower points of the spit
"Seven Mile" swamp, which latter not only received this w
also that brought down by the "Seven Mile" Creek.
western margin of the "Seven Mile" Swamp there is a sand
the lowest parts of which the natural drainage flowed, pa
Lake Grassmere, but mainly down a natural swampy vall
lies between this lake and the coastal hills, and eventually
south-eastern area of Torbay Inlet.

Lake Grassmere is a fine sheet of fresh water which i
the Marbalup Brook. It lies upon the northern side of
valley, and the water level in it stands at some few feet ab

of the saltwater of the inlet from which it was divided by a sand bank over which it discharged in time of flood.

The Torbay Inlet, which is salt, consists of two deep basins connected by a narrow neck some half-mile in length, the easternmost of which extends in the form of a salt creek for a distance of a mile in an easterly direction when it bifurcates, one branch running for a short distance to the northward being apparently the old course of the Marbalup Brook, and one to the eastward into the swampy valley before referred to which lies between Lake Grassmere and the coastal hills.

The western basin of Torbay Inlet, after receiving the entire drainage of the main valley referred to above, supplemented by that from the swampy country which lies between the coastal hills and the main plateau for a distance of four miles to the westward, discharges into the ocean by a channel some half-mile in length cut through the coastal hills.

The embouchure of this channel is closed for a considerable portion of the year by a sand bar thrown up by the sea, consequently all drainage and flood waters are impounded within these basins until such time as it rises sufficiently high to overflow it, or until an opening is artificially formed, when the scour cuts and keeps open a deep channel until the level of the enclosed sheet is reduced to that of the ocean, which latter then begins to re-build the bar.

The portion of the main valley which drains in a westerly direction is a little over six miles in length and, as previously stated, is of little elevation, a considerable area being only two feet above high water level (this of course is exclusive of those deep basins which are permanently filled with water), consequently, prior to the inauguration of a drainage system all these low-lying portions were flooded during a considerable portion of the year, or in some instances for longer periods when the flood waters failed to cut the bar.

ARTIFICIAL DRAINAGE OF THE AREA.

After reading the above it will be apparent that the drainage of the low-lying area with a rainfall of somewhere about 40 inches presents a fairly difficult problem, for given only a fall of two feet above high-water mark in the lower portions of the area and of only six feet in the same above dead low water, it will be seen that the greatest possible fall obtained from the eastern portion of this basin (which is six miles from the outlet) cannot exceed one foot in the mile.

This difficulty is further augmented by the trouble experienced in keeping the outlet open to the ocean, which may cause the water level inside the inlet to rise to a level exceeding that of ordinary high water, while further, an extra high tide accompanied by strong westerly gales may bank up the water from the inlet into the drains at its eastern end, thus causing flooding.

The drainage of this area was in the first instance und by the Lands and Survey Department, and a main drain cons along the north side of the "Seven Mile" Swamp, then south tween it and Grassmere, and thence down the valley betw lake and the coastal hills, and so into the eastern branch of th

At a later date this district was proclaimed a draina when it came under the Water Supply Department, which c the system by constructing a drain which diverted the w the "Six Mile" creek from the swamp of that name and co it directly into the main drain, while the entire volume of wat conveyed was discharged direct into Grassmere instead of conveyed round it by the old drain. A new discharge was t into Grassmere at its south-west corner, which lowered the level of that lake by some 18 inches or two feet. Under this c system the old drain which followed down along the easte southern sides of Grassmere was devoted exclusively to the d of the "Seven Mile" swamp, although the old overflow fr lake into it was not closed.

From the above it will be seen that the larger volume c water brought down by the "Seven Mile" creek was diverte its natural course over the swamp of the same name, and t the overflow of the "Six Mile" swamp and creek, which wa was also cut off, the result being that so far as the "Seve swamp was concerned it received no fresh water other t actual rainfall within the basin, and a limited amount of d from the coastal hills.

Having in the first place roughly traversed the topogr the entire basin as it existed prior to the initiation of a d system, and in the second place by the alteration made in th tion of the drainage by artificial means, the following por this report will be confined exclusively to the causes, effe suggested remedies for the overcoming of the disastrous c which prevails in the lowest lying area of the "Seven Mile" and along the course of the old drain which connects it w inlet.

EFFECT OF THE DRAINAGE UPON THE "SEVEN MILE" SWAM LAND BELOW IT.

It is claimed, and there are no grounds for doubt, that the early years that this swamp land was cultivated the s very productive; now, however, the lower lying portions h come so highly saturated with mineral solutions as to re perfectly infertile.

It is further contended that this state of affairs dated the first year of the completion of the new drainage syste owing to an excessive rainfall, so large a volume of wa brought down by the newly excavated drains and the M brook into Grassmere that the level of that lake was so materially raised as to cause it to discharge by its old outlet under what is known as the "Humpty-back" bridge, into the old drain which, presumably being choked, the water backed up in the ditches and thus flooded the "Seven Mile" swamp.

As the newly constructed drain connecting the "Six Mile" with the "Seven Mile" creek had been largely excavated through what is locally known as "Coffee rock" (ferruginous grit), the water brought down by this drain contained a considerable quantity of oxide of iron in suspension; and since the point at which the main drain discharged into Grassmere was not far distant from that at which the lake connected with the old drain, a considerable portion of this water would flow back in this direction, the consequence being that a large precipitation of this ferruginous matter took place upon this swamp, thus leaving a red-brown incrustation after the subsidence, and this it is claimed was the primary cause of the damage.

In order to avoid the recurrence of this, the old outlet from the lake into the drain was closed by filling it in at the point at which the "Humpty-back" bridge formerly crossed it.

From this date onward the infertility of this area has, it is stated, materially increased; it is therefore claimed that the flood is solely responsible for bringing about this condition of things by bringing down mineral solutions of a poisonous character which has utterly ruined large tracts of this area.

With the object of solving this problem a careful examination of the area in question has been made, all available evidence obtainable collected, and samples of soil and water analysed and reported on by the Mineralogist and Chemist, whose report is appended.

From the report it will be seen that the whole source of the trouble can be directly attributed to the decomposition of pyrite which is present in soil and subsoil of the swamp itself in considerable quantity; but in order to determine whether or no the water brought down from the higher land which lies to the northward would assist in producing a detrimental effect, a sample of water was obtained from the drain and tested, but this proved to be perfectly innocuous.

It therefore becomes clear that the flooding of this area in no way contributed to the poisoning of the land, while the phenomenon can be quite simply accounted for by the oxidation of the iron pyrites contained in the soil itself. Pyrites in its natural state is perfectly innocuous and remains so so long as it is kept from coming in contact with the air or any oxidising substance, and this fact accounts for its presence in much larger quantities in the subsoil as compared with that in the soil itself, as the former being situated below the water level is naturally protected from the air. The decomposition of pyrites is, however, brought about by either, or more rapidly by both, of the following conditions: firstly, by the drainage of the land which permits the access of the air into the soil, and secondly, by cultivation, which opens up the soil, thus exposing the pyrites to the atmosphere.

In the course of decomposition pyrite forms sulphate of iron which is commercially known as copperas, or green vitriol, and free sulphuric acid, either of which substances in considerable quantity renders the soil unsuitable for the support of vegetation.

Having arrived at the conclusion that the source of the trouble can be clearly traced to the soil itself, the next point which naturally requires elucidation is, why for a considerable number of years should it have been possible to have grown fine crops on this land while during the last few years, or since the flooding, it has proved to be sterile?

In considering this aspect of the question it must be remembered that in its natural condition the entire drainage of the country lying to the north and east flooded over the "Seven Mile" swamp, therefore when this area was first drained and cultivated this large volume of fresh water travelling in a westerly direction would carry away each year large quantities of the acid solutions. After the construction of the first drain which cut off the water of the "Seven Mile" creek a certain amount of this scouring out would cease, but still it did not seem to have affected the fertility of the land to any considerable extent until the whole system was completed, after which date, however, no fresh water other than the direct rainfall was available for the removal of the injurious salts. The flooding which took place in the same year that the drainage system was completed would, since it entered the drains by their normal out-flow, have driven back the accumulated acid solutions instead of washing them out had the flow taken its original direction.

As previously stated, this flood left large deposits of iron oxide over the surface after the water receded which, taken in conjunction with the fact from this date onward the land became infertile, naturally led the persons whose land was injured to assume that this was the primary cause of the damage, as this was the only visible one. The fact is, however, merely a coincidence, since the flood immediately followed the completion of the drain which diverted the direction of the natural flow of the surface water. The present condition of the "Seven Mile" swamp is, that it is an isolated basin the lowest portions of which are only two feet above high water and six feet above low, situated at a distance of six miles from an outlet to the sea which is closed for a considerable portion of the year.

The rainfall, although considerable, is responsible for adding little more than that which actually falls upon the area when, after allowing for evaporation, it naturally follows that only a comparatively limited quantity would be carried off by the drains, while the water remaining in them after the main rainfall period is passed becomes a very concentrated mineral solution.

The water discharged from this swamp would, therefore, contain a very large percentage of mineral matter, and since the drain which carries it off is the old one which was cut by the Lands Department along the swampy valley which lies between Grassmere and the coastal hills, this naturally becomes filled with these acid solutions since it does not receive any portion of the fresh water from the main drain; consequently when the water level of the inlet rises after the first heavy rains, this water is forced back and floods the low-lying areas, thus rendering these also infertile.

SUMMARY.

(1) The poisonous mineral solutions in the soil of the "Seven Mile" swamp are due to the oxidation of the iron pyrite in the soil itself owing to this mineral being brought in contact with the air by drainage and cultivation.

(2) So long as a large volume of fresh water traversed the swamp the injurious solutions were removed as rapidly as formed, but that this removal ceased to a considerable extent when the course of the natural drainage was diverted.

(3) The cause of the damage to the swamp-land lying in the valley between Grassmere and the coastal hills is due to their flooding by the acid solutions drained from the "Seven Mile" swamp.

REMEDIES.

There are only two remedies for the prevailing condition of this, namely, drainage and limeing—the former of which, coming within the province of the engineer controlling the drainage areas, will not be dealt with in other than a series of suggestions the feasibility of which must be left for those qualified to deal with them.

1. If means could be devised whereby an outlet to the sea could be kept permanently open, with flood-gates to prevent the inflow of high tides, a fair natural drainage of this area might be obtained.

2. If a series of high level channels were constructed into which the mineral water in the low level ditches could be pumped by wind or other power similar to the system adopted in the Fenlands of England and Holland.

3. If a main canal was cut south across the swamp from the point at which the "Seven Mile" creek crosses the railway line, from which smaller drains were cut in a westerly direction in a similar manner to an irrigation system, the fresh water traversing these would in the course of its passage drive before it and thus wash the injurious solutions from this area.

4. Limeing without drainage would be impracticable quantity of this basic mineral required to neutralise the soil waters would be so great that the cost would ma hibitive.

Mr. Simpson recommends the application of burnt l first place, followed by ground limestone in the second. these would, however, be costly unless permission was o remove stone from the adjoining Crown lands, when k small crushing plant could be erected which would materi the cost and thus allow of a liberal application, sa tons to the acre, as a first dressing of burnt lime, quently one ton of limestone annually until the acid i was overcome, after which the yearly dressing would be governed by conditions.

5. It must further be remembered that the trouble is presence of the acid and acid salts, therefore the app acid phosphates such as "Super" are only adding to th therefore it would be advisable to substitute this by any lowing: Thomas' Basic Slag, Bone Dust, Abrolhos Guano Rock Phosphate; the latter for preference, since it is gu contain 84 per cent. of phosphate of lime, and in consequ go from two to three times as far as the others, while th phuric acid in the soil would render the phosphoric oxide in fact convert it into super.

CONCLUSION.

This acid poison after drainage of lands is of qui occurrence, in fact is to be expected; but since in the n cases the natural character of the country lends itself t ficial drainage, these injurious solutions can be removed as they are formed, consequently no injurious effects enced. Here, however, the natural gradient of the surfac causes stand in the way of a simple drainage system, an to a more or less complicated engineering problem, whic there is little doubt will be overcome.

BULLETIN No. 74, PLATE IV.

etcher, Government Lithographer, Perth, W A

APPENDIX.

Soil and Water from Grassmere District.

nade a preliminary examination of the soils and water from the istrict, collected by Inspector Vaughan. The soils are said to eviously fertile, but to have recently become barren.

er proves to be strongly acid and to contain in solution abundant l chlorides of aluminum, iron, lime, magnesium and alkalies. Such in small quantities, would have a fatal effect upon any vegetation nad access. On exposure to air it would slowly deposit a rusty nd such as that referred to by Mr. Vaughan.

e soils are peaty swamp soils, strongly acid in reaction. Those les and bottom of the drain are impregnated with pyrites and e salts (sulphates and chlorides) of aluminum, lime and mag- at from the top appears to be free from pyrites and to contain r quantities of soluble salts. Such strongly acid and saline soil ossibly support vegetation of any kind.

se of the trouble is that the soil in these swamps, like those in the od of Perth, contain a considerable quantity of finely divided hide of iron) below the level to which air penetrates into the soil l undrained conditions, say two feet down. When the water red by drainage the pyrites is subjected to the action of the air, rts it into a mixture of iron sulphate and sulphuric acid, both of ompletely destructive to vegetation.

nedies are:—

To ensure rapid removal of the water from the soil and surrounding drains and to refrain from returning to the ground any water from the drains;

To dress the surface of the soil heavily with burnt lime at first and with ground limestone later;

To use basic fertilisers and never acid ones such as superphosphate.

EDWARD S. SIMPSON.
Mineralogist and Chemist.

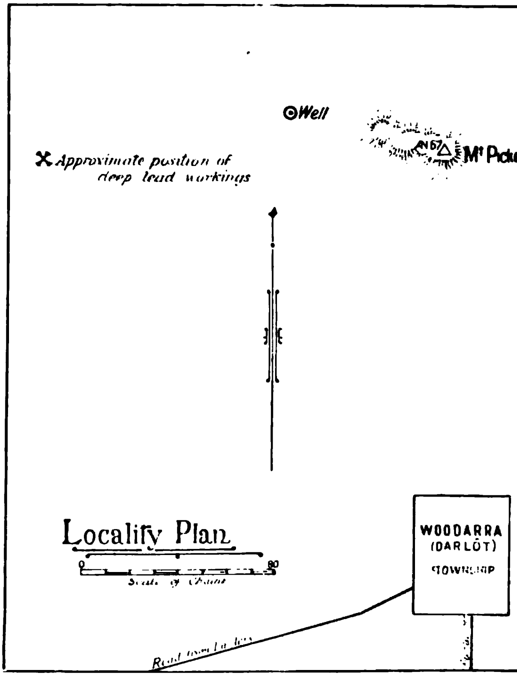
65.—THE DEEP LEAD AT DARLÔT—EAST M GOLDFIELD.

By J. T. JUTSON.

(With three Figures, 5, 6, and 7)

The workings pertaining to this deep lead are si
three miles to the north-west of Darlôt (Woodarra), on
Area 647, which is held by the Darlôt Deep Lead Syndic
and party) (Fig. 5). The country is quite flat in th

Fig. 5.


Well
Approximate position of deep lead workings
N 67
Mt Pick
Locality Plan
0
80
Scale of Chains
WOODARRA (DARLÔT) TOWNSHIP
Road to

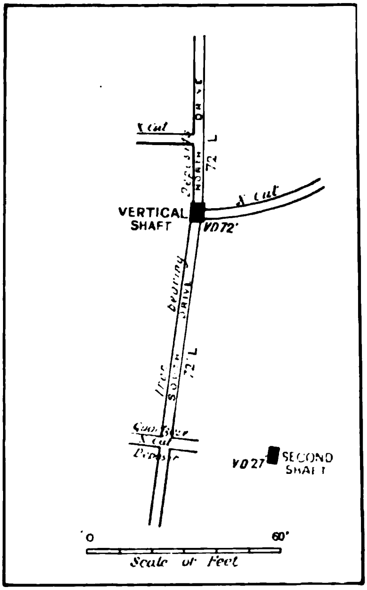
Locality Plan showing approximate position of D
Deep Lead Workings.

vicinity of the workings, but some ridges and hills o
short distances away, part of the drainage of which
the flat. This flat is covered by detrital laterite and cla

are no outcrops of any rocks, but from the nature of the surface material, the chief rock appears to be greenstone. Granite was stated to occur in various directions from the prospecting area, but none occurred (it was said) nearer than about five miles.

The workings on this prospecting area at the time of my visit are shown on the accompanying plan (Fig. 6).[1] They consist of

Fig. 6.



Sketch Plan of the Workings P.A. 647, Darlot Deep Lead.

a main vertical shaft 72 feet deep, from which all the "driving" and "cross-cutting" have at present been done. From the bottom of the shaft there is a drive (the "north drive") north for 50 feet. At 19 feet from the shaft, a crosscut west has been made for 18 feet. From the shaft a curving crosscut east has been made for 38 feet. South from the shaft there is a drive (the "south drive") for 95 feet. At 68 feet from the shaft a crosscut west for 10 feet and a crosscut east for eight feet have been put in from this drive.

At a distance of 74 feet in a direction about S. 18deg. E. from the main shaft another vertical shaft was being sunk, and had reached a depth of 27 feet. It is the intention of the owners to continue this shaft to the bottom of the wash, and then to connect with the east crosscut from the south drive of the main shaft. That having been done it is then proposed to take out abou tons of the wash for the purpose of a trial crushing. for sinking the second shaft and making the proposed is that the water in the south drive and crosscuts make of extraction and haulage too difficult. It is believed th ing of the second shaft will much facilitate this work.

---

[1] This plan is based on that prepared by Mr. H. Colbran, Inspector of Mines, with some slight additions, bringing the work done up to the 28th September, 1913 (the date of the present writer's inspection).

The drives and crosscuts are only about 4 feet or 4 f high, and about 3 feet broad. They have been timber extent, this being absolutely necessary on account of t nature of the ground.

The low height and small width of the drives an combined with the fact that the water was at times knee- the examination of the ground difficult.

As far as could be seen descending the main shaft the material through which this shaft had been cut co the surface of several feet of detrital laterite, arrange horizontal layers and cemented by oxide of iron. Belo were iron-stained clays, with bands and irregular patc stone pebbles, and near the bottom a few small quart were seen. The whole of the material may be described in the sense that it has not resulted from the decomposit *in situ,* but there is little evidence of much transport of component parts, and this despite the fact that many stone pebbles are rounded; for such rounding (for s at least) is probably due to concretionary action before reached their present positions.

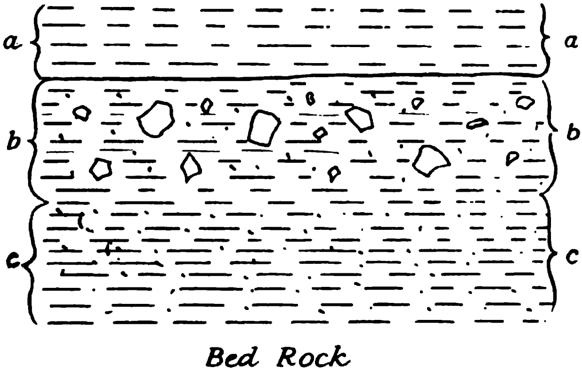
Along the north drive, the west crosscut from tha crosscut east from the main shaft, and the south more than 50 feet, the material is much alike. It is und detrital origin and consists principally of iron-stained ironstone pebbles from one quarter of an inch to th inches in diameter and frequently rounded, such rou partly due to attrition, and partly to concretion Scattered through these deposits is an occasional f quartz, sometimes angular and sometimes well rounded. was informed that these iron-bearing deposits, as t termed, carried traces of gold, but were regarded as Throughout the portions just described, no undoubted b be seen. The iron-bearing deposits practically occupy height of the drives and crosscuts, but in places a white free from coarse detritus, could be seen above.

In the east and west crosscuts of the south drive, latter south of the crosscuts and for about 12 feet n crosscuts, the wash is different from that hitherto descr distinct bands can be seen (Fig. 7). On a level with the workings a white very "puggy" clay occurs, which contain scarcely any grains or fragments of quartz, i other material, being practically homogeneous, with numerous small irregular planes, which are smoothed and striated, and which thus prove that considerable local movement must have taken place in

Fig. 7.

DARLOT DEEP LEAD

Section. of auriferous wash 4ft 6 in thick in east cross-cut of south drive 68 ft from main shaft :—



(a) Non auriferous wash. composed of white clay almost free from grains or fragments of quartz ironstone, or other detrital matter

(b) Auriferous wash. composed of white clay with numerous angular, and subangular fragments of quartz. and some of ironstone The fragments vary in size from a grain to 3 or 4 inches in diameter

(c) Auriferous wash. composed of white clay, and chiefly grains of quartz. Few large detrital fragments.

Section of Auriferous Wash, 4ft. 6in. thick, in East Cross-cut of South Drive, P.A. 647, Darlot Deep Lead.

the mass.[1] It was stated that this material practically carried no gold. Below this, and separated by a sharp line was similar white clay, but mixed with it was an abundance of fragmental quartz. These fragments varied in size from flattish pieces about four inches in diameter to grains about the size of a pin's head. Both grains and fragments up to about one and a-half inches in common. The large pieces of quartz were generally quit but at times were slightly rounded at the corners. The sm were also angular, but the most numerous pieces (from a q to about one and a-half inches in size) were often sub-an partly rounded. Here and there an extremely rounded sn occurred, and a fair number of similar ones (which had b out from time to time by the owners) were shown to Taken as a whole, however, the fragments were angular angular. They showed some evidence of attrition, but th of the fragments must have travelled but a comparati distance. The extremely rounded forms may be regarded ing a small minority of the whole, and the contrast bet and the more numerous fragments is so great that it is sible that these very rounded pebbles belong to a pre-exist deposit, and have since been incorporated with the mo deposits of the present deep lead.[2] In the wash were rounded ironstone nodules from a quarter-inch to two inc meter. Some of these are probably of concretionary ori inclusion in the deposit. There were also some few ro pebbles of a decomposed rock, apparently a greenstone.

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[1] This is also shown by the fact that some of the soft earthy pebbles of the coarse wash have been planed and striated.

This coarse-grained deposit would average between two and a-half feet in thickness. It passed irregularly ally into an underlying deposit, which is generally from to two feet in thickness (so far as seen, and this is probab but neither its lower margin nor the bedrock was visible of the water, and of the floor being covered with wash from of the drives and crosscuts). This last-mentioned depos of the same "puggy" white clay, with the larger fragments and ironstone generally absent, but small quartz grains numerous. Both the coarse and the fine wash were state gold, but the fine wash was regarded as being the richer.

Going north along the south drive from the crosscuts quartzose wash appeared to gradually pass into the ir deposits already described, at a distance of about 12 feet crosscuts. Going south the coarse band loses its identi apparently dying out, but the fine band is maintained, al gold was said to be becoming scarcer. The coarse ma appears to be dwindling in the west crosscut.

No cross-bedding or stratification bands (other than and fine ones mentioned) were noticed in the quartzose de far as could be observed, they appeared to have a slight south-west, but this is not too certain.

In the south drive, near the junction of the cros granitic boulders, somewhat rounded, and being about 9 an respectively in length, were noticed on the floor of the drive. The writer was informed that they occurred at the bottom of the wash, and presumably on the bedrock. This granitic rock [13295] has been examined by the Petrologist, who describes it as a very felspathic facies of a fine-grained granite or porphyrite, with actinolite, and deficient in quartz. The occurrence of these boulders is curious, as no granite is seen on the surface for some miles around. It is evident that granite, perhaps as a dyke, must be close to the surface in the neighbourhood of the deep lead; and it may be largely responsible for the small quartz grains and the kaolinic-looking clay forming such a feature of the detrital deposits.

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[2] If this be so, some of the gold may also be of similar origin.

Another interesting point is that, in the south drive, south of the crosscuts, a "bar" of hard rock, about three inches in width, was stated to cross the drive, and to project above the decomposed bedrock for about a foot in height. This "bar" was unable to be seen, but a specimen of it was handed to the writer. If it occur as stated, it is probably a small dyke, which has resisted erosion more than the adjacent rocks. It also shows that the bedrock has been reached.

This rock [13297] has also been examined by the Petrologist, who points out that, although quartz is conspicuously absent, there is a close resemblance to [13295] and suggests that they may be genetically connected, [13295] being slightly more acid than [13297]. The latter, he states, has some similarities to the non-porphyritic phases of the albite-porphyrites, and it may therefore be regarded as a felspathic facies of a granite with actinolitic hornblende, or as a very felspathic phase of an amphibolite; more probably the former.

The field and microscopic evidence therefore suggests that [13297] is a small dyke cutting through the bedrock of the lead, and that the boulders of [13295] are probably derived from a different phase of the same or another similar dyke.

Several dishes of the quartzose deposit were washed and mostly gave fair prospects of gold, the latter being coarse as well as fine. Several quartz fragments containing free gold were shown to the writer, and they were reported to have come from the quartzose deposit.

The second shaft that was being sunk contained material generally similar to that of the main shaft, but no quartz fragments were noticed. Irregular bands and patches of gypsum occur.

A few yards to the east of the shafts mentioned are several old shafts (now inaccessible) which were apparently sunk to work the deep lead, but from which payable wash had not evidently been obtained. The material thrown out was much akin to that which has been described above as the iron-bearing deposits.

Taking all the facts into consideration, it may be stated that a true auriferous detrital deposit occurs, which in accordance with the usage in Western Australia may be described as a deep lead.

The extent, thickness and direction (except possibly to the south-west as to direction) cannot be given, as insufficient work has yet been done, and the surface throws absolutely no light on these questions. The old workings and most of the present ones are probably not in payable ground, but the quartzose deposit (which was discovered by careful, economical, underground prospecting) undoubtedly carries some gold, but whether payable or not will probably only be determined satisfactorily after 40 or 50 tons have been crushed, such crushing being advisable in consequence of the heavy wash in places, and the hard nature of some of its components. The prospects appear to be sufficiently good to further prosecute the work, to enable this trial crushing to be made. This further work may also demonstrate whether the quartzose deposit is a mere "pocket" (as to some extent appears probable), or whether it represents a portion of an ancient well defined stream-bed deposit. At present no distinct "gutter" can be said to have been located.

3rd October, 1913.

PORTED OCCURRENCE OF OIL NEAR WONNERUP —SOUTH-WEST DIVISION.

By E. de C. Clarke and H. P. Woodward.

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samples of supposed Petroleum-bearing earths and water
onnerup—E. S. Simpson 70
iver Prospecting Area—H. P. Woodward 71

Introductory.

1st and June 1st and 2nd, 1915, were occupied in travel- examining the neighbourhood of Block 687, near Won- re indications of petroleum were reported to occur.

867 (see Plate V.) is about four miles in an east-south- on from Wonnerup Junction, which is six miles from nd 143 miles from Perth. It lies on the Coastal Plain th-West, which is described by Messrs. Saint-Smith[1] and Vhere uncultivated, the surrounding district is forest- dering on the block, however, is a treeless area of about miles, covered only with stunted vegetation. The Abba eandering watercourse, discharging into the Vasse Estu- cross the block in a north-westerly direction, but has no rse in the part with which this report deals.

Character of "Indications."

ortion of Block 687 from which the most pronounced " are reported, was, until cleared by the owners, covered dinary forest. The surface is almost level with the ex- low mound, known as "the Bank," which rises about six

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V.A. Bull., No. 44 ., p. 8, *et seq.*
V.A. Bull., No. 61·, pp. 41, 171, *et seq.*

feet above the surrounding plain, and, running in a ge west and south-east direction for about 18 chains, pass at both ends into the general plain (see Plate VI.). Th dence that the "Bank" marks an anticline or any oth feature of importance. About 20 chains away from house is another slight elevation occupied by a clump marking an occurrence of "ironstone" (ferruginou which also is of no significance for the purpose of th

Unfortunately, at the time when the visit of a g requested, the "indications" had been almost entirely heavy rains. Iridescent scums were pointed out to t some of the pools occupying the course of the Abba Wonnerup, and also on the wells near the farmhouse. apparently mobile, but did not, when disturbed, give t curved or convoluted figures" of undoubted oil films. iron oxide films.

As no promising surface indications were to be time of the writer's visit, the following summary of tions" observed by the owners may be of some interes

"Indications" were first noticed about the end of on sinking well No. 1 (see Plate VI.) to a depth of abo strong 'smell of kerosene' was noticed. The water c be drunk either by man or beast. When a well is new ground, the water often improves with baling, provement did not take place in Well No. 1. Sometim would be covered with a sheet of oil so thick that a pi easily been collected. Moreover, oily drops, as much a diameter, would often be seen floating on the water. these drops would break up and form either an irides chains of minute globules and at the same time a sh red dust would sink to the bottom.

The best "indications" are seen during the hot w December to March. The winter rains almost comple them. However, between July and November of each y occur on all the puddles over the area under discussio

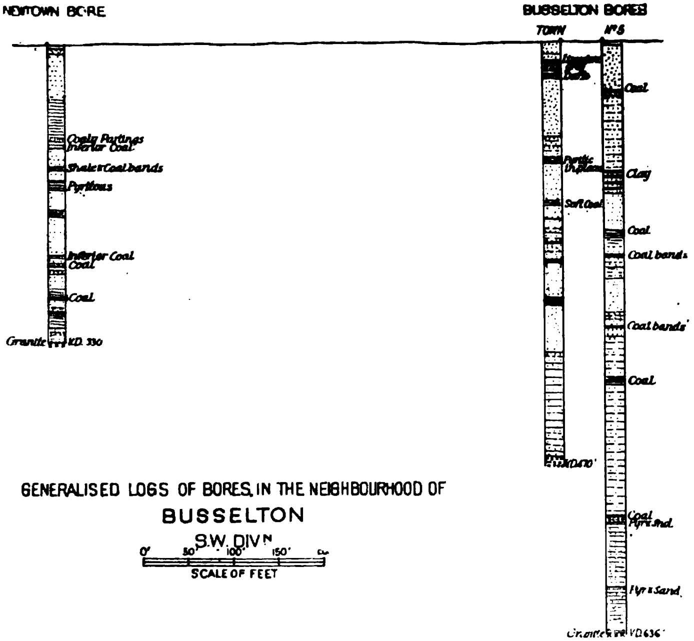
The absence of trees from the area near Block 68 to be due to the evil influence on plant life of petroleum panying saline exudations.

The writer wishes to make clear that, while he is no for any of the observations in the last three paragraph that they were recounted to him in all good faith. It chemical investigations have failed to reveal any trace in strata from these wells, but it has frequently happe parts of the world that disagreeable tastes and smells draining swampy ground have been mistaken for the t of "kerosene."

GEOLOGICAL EVIDENCE AS TO THE POSSIBILITY OF THE OCCURRENCE OF OIL IN THE NEIGHBOURHOOD.

As will be clear from Section 1, the area dealt with in this report is devoid of geological evidence as to the possibility or otherwise of the finding of oil. Regarding the whole surrounding district, moreover, the geological facts of value in this connection are very few. In Saint-Smith's report [1] the neighbourhood of Block 687 is shown to be underlain by recent and post-tertiary sand, clay, and gravel to a depth of one or two hundred feet, beneath which come 500 feet of doubtfully mesozoic rocks—the Donnybrook Beds—but the thicknesses of the respective series are largely conjectural. Underlying the Donnybrook Beds is granite, from which of course no petroleum can be obtained.

Fig. 8.



Generalised logs of bores in the neighbourhood of Busselton.

According to one widely accepted theory, petroleum and kindred substances originate most frequently, if not always, from the natural distillation of coaly matter. In support of this theory it is frequently found that the strata of a proved oil-bearing locality

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[1] *Loc. cit.*, Plate II.

are devoid of coal seams, whereas if the same beds ar
a neighbouring area where barren of oil they will pro
coal seams or other traces of vegetable matter.

Plate V. shows the position of certain bores put dov
ago in this district in search of coal. A simplified dia
the strata passed through in three of these bores is als
8). It will be seen that in each bore thin seams of c
but no trace of oil or gas was recorded.

Again, it is known that coal occurs in the Don
further east.[1] It is, therefore, rather unlikely that in
687 those coal seams which exist unaltered both to th
the west will have been changed to petrolaceous subs

Beds of the same character and probably of the sa
in the Blackwood River District, and despite a good
have not been proved to be oil bearing.[2]

Summarising: geological evidence as to the possi
occurring in or near Block 687 is, in the absence of
of bores in the immediate neighbourhood, very scanty.
there is is unfavourable.

METHOD OF COLLECTING SAMPLES.

The collecting from the most favourable localities
liable samples for analysis was undertaken. A new w
Plate VI.) was dug by the owners to a depth of 11 fee
bored by hand to a further depth of 11 feet. Sample
terial sunk and bored through were taken. A bore
down from the bottom of No. 1 well a further 11 feet
ings kept. The strata passed through are noted on ins

If oil is sufficiently abundant in these beds to exud
time to the extent reported in Section 2, we should ex
piercing of hitherto untouched strata would, even in wi
a noticeable amount, more particularly as the clay pa
in both bores was well suited to prevent the escape o
would presumably have kept considerable quantities sea

After 12 hours the water which had collected in
showed such a very slight film that no satisfactory samp
been taken. The owners, however, after allowing the
accumulate for some days, obtained the sample of wa
reported on below.

Portions of a sample of sand and clay from We
been treated by Mr. M. A. Browne, at Ravensthor
yielded an appreciable amount of a substance which ap
a hydrocarbon. Mr. Browne records, however, that the
been moistened with water from No. 1 Well, on which
to have been floating at the time. Through the kind

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1. G.S.W.A. Bull. 44., p. 25, *et seq.*
2. G.S.W.A. Bull. 65.
3. Scale of inset should be 20ft. to 1in.

Browne the balance of this sample was secured for further examination and is referred to in Mr. Simpson's report as "Browne's Sample."

In conclusion, I wish to record my thanks to the owners of Block 687 for their courtesy and ready help both in giving information and in carrying through the re-sampling of the supposed oil-bearing rocks.

12th July, 1915.

APPENDIX

ON SAMPLES OF SUPPOSED PETROLEUM-BEARING
AND WATER FROM WONNERUP.

The samples submitted consisted of five lots of wet sand an
from shallow depths and a sample of water from a well sunk in t

There were no visible indications of petroleum-residues in
samples.

Since liquid petroleum consists largely of oils which are vo
air at the ordinary ground temperatures reached in the day time in
it is highly improbable that any liquid petroleum should exist i
porous earths obtained so near to the surface. Had petroleum
however, penetrated into this earth, it would have left behind
of those typical non-volatile residuals, paraffin wax or asphaltu
ments were therefore made with a view to extracting any such
determining its nature and amount. Quantities of earth were tak
one part per million of asphaltum or paraffin wax might be recogni
common solvents were available for extraction, viz., carbon bisul
and petroleum spirit. Paraffin wax and liquid petroleum are co
readily soluble in all three, asphaltum is completely soluble in
phide, whilst ether and petroleum spirit dissolve from 40 to 100
weight of this substance. At the same time it is to be rememb
three are powerful organic solvents capable of dissolving many oil
other substances of vegetable and animal origin, such as have be
exist in many soils.

For various reasons carbon bisulphide was not used as a sol
five earths were extracted by both ether and petroleum spirit,
tracts evaporated at room temperatures to recover any dissol
No trace of petroleum or either of its typical residuals was found i
five earths. The five samples tested were marked 516c, 517c,
and " Browne's sample." The last named enclosed in its midst
which may or may not at some time have come in contact with
or animal oil.

No indication of petroleum or petroleum residues could be
the water sample, which, however, was greatly contaminated b
dying animal and vegetable matter.

EDWARD S. SIMPSON,
Mineralogist an

8th July, 1915.

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THE ABBA RIVER OIL PROSPECTING AREA—SOUTH-WEST DIVISION.

This area, which covers 3,000 acres, is situated upon the coastal plain about four miles south-east of Wonnerup and about eight miles east of Busselton.

The coastal plain in this locality is nine miles in width, running in a north-east and south-westerly direction, being bounded on the north-west by the sea and the south-east by the laterite-covered scarp which extends from the Collie River to Cape Naturaliste.

The Abba River takes its rise in the elevated laterite-covered and jarrah-clad country which lies to the south-eastward of this scarp, from which it flows in a well-defined channel for a distance of about three miles, one mile of which is included in the south-eastern corner of the prospecting area.

At this point the river spreads out over a wide flat which, during the rainy season, it mostly covers with a shallow sheet of water; the only portions not so flooded consist of low eminences upon which "black butt" and other timber flourish, while the open flats are destitute of timber but for the most part covered with rush-like growth.

On this level tract of country open flats destitute of vegetation are fairly common, upon the surface of which an incrustation of salt is often present during the dry season, this being apparently due to the evaporation of the salt contained in the run-off water from the hills supplemented by previous accumulations contained in the soil of which these swampy areas are composed.

Upon the northern margin of this area, in which direction the surface of the country gradually falls, the water brought down by the Abba from the hills accumulates in swamps which eventually are drained by a defined channel which discharges into the Vasse Estuary.

Upon Location 687, which is situated at about the centre of this area, the Wilkinson family, who own this property, which is known as Seven Oaks, discovered in sinking a well that the water after being allowed to stand for a short time was covered with an oily substance, which gave rise to the assumption that deposits of mineral oil existed in this locality.

With the object of further testing this question a number of holes were sunk, in all of which when water was struck, which is usually at a depth of about eight feet, what is called by the Wilkinsons the oil phenomena, may be observed.

Upon the area itself no geological features can be observed, since the only rocks visible are clays in the flats, with loamy rises

and occasional outcrops of laterite; while to the s
scarp of laterite-covered sandstones and shales
Donnybrook Series rises abruptly from the plai
west at a distance of about two miles from the
cherty limestone country about one mile in widt
timbered, largely with tuart. This limestone is t
sion of the Marine limestones at Capel, which con
and corals of existing species. It is, therefore
assume that these beds are of the same age and
a shallow sea.

Westward of this limestone belt there is a lo
exists a chain of swamps and estuaries into whic
the land to the eastward is discharged, while thes
themselves into the sea through the Wonnerup Inle
paratively narrow gut cut through the line of lofty
fringe the coast line. The contentions advanced b
as evidence of the existence of mineral oil are (a
the surface of the water in the shallow wells a
ebullition of gas which rises in bubbles through
also observed to rise from the earth subsequent
flooding of the flats, in which case blow holes a
surface water has subsided; (c) drumming soun
in certain localities when a horse or cart passes
(d) the failure of vegetation in patches upon th
(e) the occurrence of sandstone in the trial hole
patches on the surface of the ground.

Taking these in order, I have arrived at th
clusions:—

(a) There is undoubtedly an oily substance up
the water in the wells, that on the swamps I was
as they were dry. This greasy film is very comm
in the swampy areas of the south-west, and is qu
the iron scum as it flows on the surface of water.
this film covers the surface of the water after b
regulated by the atmospheric temperature, thus it
siderable time to close in the early morning but
the hotter portion of the day.

This film is so thin that even after repeate
quantity of oil collected is practically inappreci
stated that if these skimmings are reskimmed and
that the oil evaporates through the cork. This la
be an error, and would suggest that the oily film
the inside surface of the glass and thus vanishes
of the water.

The composition of this oily matter has as
termined, but I am of the opinion that it is of

probably exuded from the roots of the rushes, as I have never observed it in any locality where these do not grow.

(b) Ebullitions of gas.—These can be observed if the muddy bottoms of the holes or pools are disturbed. This is quite a common phenomenon, being due to the liberation of sulphuretted hydrogen gas the origin of which is the decomposition of any vegetable matter, and is of very common occurrence in all swamps.

The supposed gas blows could not be observed as the ground was all dry, but the blow holes were distinctly visible; these, however, I attribute to the escape of air held in the soil, which is first covered by flood water and then driven out by the descending water soaking the ground. A similar effect can be readily produced by filling a flower pot with fine dry earth and submerging it in a bucket of water, when the air contained in the soil is driven out with a similar formation of blow holes.

(c) The drumming sound noticed in crossing the surface is very common, being due to a hard crust or layer of rock at or near the surface, beneath which is a dry stratum containing air; this is not to be observed in the rainy season as the interstices in the substratum would then be filled with water.

(d) The failure of crops to grow upon patches on the cultivated land is not necessarily caused by the exudations of mineral oil, but is more probably due to the rise of saline water drawn up by capillary attraction. This action is induced by cultivation and is therefore not observed on the untilled land. It may be mentioned here that all the water encountered in sinking upon this area is saline, and probably contains chloride of magnesia as well as soda; I have not, however, the results of the analysis of the sample collected by Mr. Clarke.

(e) Occurrence of sandstones in the trial holes—This is looked upon as an indication by the prospectors who, in reading up the subject, find that sandstone was invariably one of the rocks met with in all the noted oil fields. The sandstone in question is of a ferruginous character and presents more the appearance of an iron-cemented sand bed similar to the deposits so frequently met with in swamp beds, since all evidence of bedding is wanting.

(f) The presence of salt is also advanced as an indication of the presence of petroleum as this substance has invariably been found in association with it.

From the foregoing it will be noticed that all the so-called indications are of extremely common occurrence in other parts of this State, while the oil, although its true character* has not as yet been determined, is clearly not petroliferous, otherwise horses, which are most particular and possessed of a wonderful sense of smell, would not drink of it.

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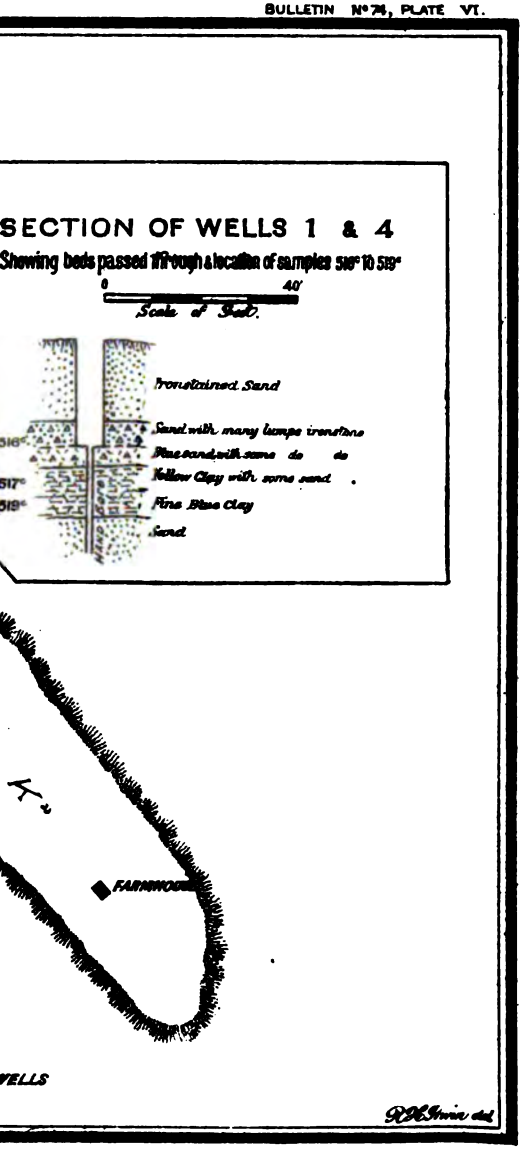
* NOTE.—On 8th July, 1915, Mr. Simpson did report that there was no indication of petroleum or petroleum residues in the water sample collected by Mr. Clarke.

If, however, for the sake of argument we allow that represents a petroliferous seepage, we must naturally concl the impervious cover beds essential to the retention of oil i terranean reservoir are absent, therefore boring in search would be naturally useless since at best low-grade petrolifer could be expected.

In conclusion, I am reluctantly compelled to state th a careful examination of the area, and after weighing the evidence adduced in support of the existence of petroleum in this locality, I find that all the so-called oil phenomena attributed, and in my opinion are, to much simpler causes fore, although it is impossible for me to make the statem oil does not exist in this area, I can safely state that absol indications exist of its presence in this area, which is ide every way with many thousands of square miles of territor State.

23rd March, 1916.


SECTION OF WELLS 1 & 4
Showing beds passed through & location of samples 516c to 519c
0
40'
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Ironstained Sand
Sand with many lumps ironstone
Fine sand with some do do
Yellow Clay with some sand
Fine Blue Clay
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WELLS
R.H. Irwin del.

H. J. Pether, Government Lithographer, Perth, W.A.

67.—THE CHEMICAL AND PHYSICAL PROPERTIES OF SOME OF THE DONNYBROOK SANDSTONES.

By Edward S. Simpson.

(With a map, Plate VII., and two figures, Nos. 9 and 10.)

Note.—Six samples of sandstone representative of the various quarries at Donnybrook, and from different horizons in the same, were submitted by the Chief Architect for the express purpose of having an investigation made by the Laboratory Staff, with the view of determining their relative durability as building material. The quarries are situated on the Bunbury-Bridgetown Railway line, 132 miles from Perth, and at elevations approximating to 200 feet above sea-level.

A. GIBB MAITLAND,
Government Geologist.

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Introduction.

During the last fifteen years a number of quarries, all of them as yet comparatively small, have been opened up in various places within a radius of about three miles of the railway station at Donnybrook, where there is a considerable development of almost horizontally bedded sandstones of unknown age.[1] The stone from these quarries has gradually won its way into favour with the metropolitan architects, who now recognise its artistic appearance and practical utility for a large variety of structures. Experience of

---

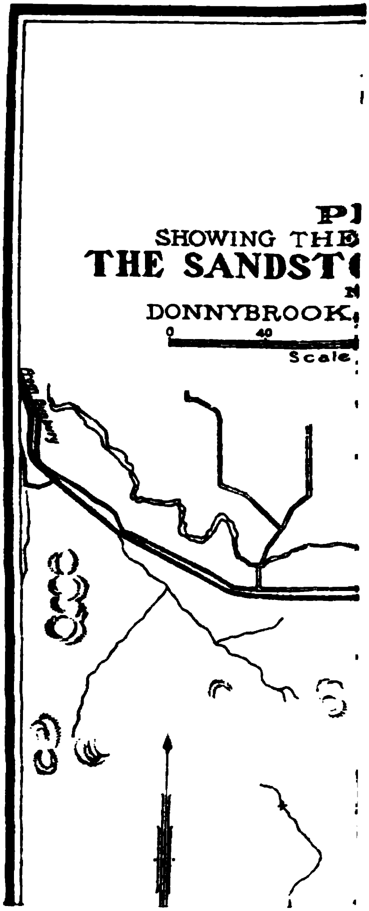
[1] Only a single very imperfect fossil (mollusc ?) has been obtained from these beds, viz., from the Government Quarry.

its lasting qualities is however limited, owing to the short t
ing which it has been in use, to the various localites from v
stone has been derived, and to the small development of the
from which it has been won. In view, therefore, of the
importance of the stone as a building material in the city
and of the large expenditure proposed to be made on a new
Post Office, it was considered advisable to obtain some defi
regarding the strength and probable durability of the vario
of stone obtainable from the different quarries in the Do
area.

In general the workable Donnybrook stone may be des
a felspathic sandstone whose principal binding is kaolin o
site. In colour it varies from pure white to deep buff or e
ally deep pink, the paler coloured stone invariably darkeni
on exposure to the air. In grain it varies from very fine t
ately coarse. The stone is obtainable in large blocks of eve
and in those which reach the City current bedding and "sa
i.e., poorly cemented patches, are rarely seen, and flinty
never. The stone is easily worked by machine or by ha
freshly quarried, but hardens distinctly on exposure to dr

Originally six different stones, each in duplicate, were s
by the Chief Architect as representative of the quarries a
brook, and subsequently a seventh was obtained from the
ernment quarry. With them was a "Sydney" sandstone
parison. From my own experience, however, of Sydney s
I am of opinion that this latter stone did not come from a
important Pyrmont or other quarries of "Hawkesbury Sa
within the boundaries of the New South Wales metrop
from some quarry outside that area and nearer to the ed
basin in which the rock has been deposited. This opi
shared by a Sydney architect to whom the specimens w
mitted. I shall therefore, in order to avoid misconception,
this rock as "Hawkesbury" stone, recognising that it is deri
the Hawkesbury Series, but that its exact locality is uncer

It will be convenient to state early in this report the
value I place on the stones for building purposes, and giv
subsequently. At the outset, however, it is necessary to dra
tion to the fact that no quite satisfactory value can be p
any sedimentary rock for building purposes without more d
are at present available with regard to these stones, of th
importance being a crushing test on thoroughly wetted st
a comparison of physical properties of portions of the sa
before and after actual exposure to the weather for at lea
months. As Donnybrook stone promises to become the
portant building material in Perth, such tests should be ca
as soon as possible by the Government Architectural Branc
junction with Geological Survey Laboratory.


P
SHOWING THE
THE SANDST
DONNYBROOK
0
40
Scale

The relative building values of the stones submitted, having regard to their strength, durability, and general fitness, are as follows:—

(1) } Quarry No. 1, Loc. 1244, North Donnybrook.
(2) } Government Quarry, Res. 2720, North Donnybrook.
(3) "Hawkesbury," New South Wales.
(4) Goldfields Quarry, Loc. 535/152, South Donnybrook.
(5) Quarry No. 3, Loc. 48/1924, North Donnybrook.
(6) Armstrong's Outcrop.
(7) Arnott's 1st Quarry, Loc. 48/1991, North Donnybrook.
(8) Pink Quarry, South Donnybrook. Stone at eight feet.
(9) Pink Quarry, South Donnybrook. Stone at surface.

Owing to the disappearance in transit of specimens of the best Sydney sandstones from the Pyrmont Quarries with which I had arranged to be supplied, I have been unable to make any close comparison with this greatly used stone. In the absence of specimens it was also impossible to compare in detail the Donnybrook stones with what is usually considered to be the best freestone in Victoria, viz. that from Stawell. Many details regarding the latter are to be found in the *Proceedings of the Royal Society of Victoria*, Vol. XXII., pp. 172-197.

Tests applied.

The strength and durability of a sandstone depend mainly upon three factors:

A. The relative quantity of quartz, a practically indestructible mineral, amongst the sand grains.

B. The relative proportions of grains of various sizes. It is just as essential in a sandstone as in a good mixture for concrete that there should be sufficient smaller grains of various sizes to fill in the large spaces between the coarse grains.

C. The tenacity and durability of the binding material under the varying conditions of exposure in a building. This is the most important point of all, since though the sand-grains individually may be strong and durable, without a strong and durable cementing material the stone in mass will ultimately approach to the condition of a mere sand without coherence.

In order to elucidate these points the following tests were required:—

(1) *Crushing Test of Dry Stone.*—The utility of this test is obvious, and figures for it were available from the testing plant at the Midland Junction railway workshops.

(2) *Crushing Test of Wet Stone.*—This should be made on duplicates of the same blocks after thorough saturation with water. The surface of a sandstone in the outer walls of a building is frequently, owing to its great porosity, saturated with water to a greater or less depth during the wet season, and in this condition

the stone is still subject to the usual compressive stress
superincumbent weight, as well as to the scouring acti
wind, and, to some extent, of sand grains and passing t
all sandstones the cementing material consists to a grea
extent of colloidal minerals of the clay group, which w
ably soften when wetted and may even pass into a slurry
all cementing power. It is evident, therefore, that a w
test is of great importance in the case of sandstones.
figures are, however, available in these cases, and hand c
which was resorted to, is very unsatisfactory, though
in the case of the stones from the Pink Quarry were one
causes why they were placed so low in the list on page

(3) *Actual Weathering Tests.*—These would be of
value, if carried out under scientific control, over definite
time, and under identical conditions, on a series of block
different quarries, each block being cut into a number
small masses, with comparison of physical and chemical
before and after the exposure. No such tests have yet
but they should be inaugurated immediately. In the
such tests, an examination has been made of buildings i
whose age is known as well as the source of stone. S
amination would in any case supplement the scientific te
of the more important structures in which Donnybrook
been used is given on page 91.

(4) *Artificial Weathering Tests.*—Many laboratory
been devised from time to time which are supposed to
a few hours or a few days the effects of years of weathe
tests are all extremely artificial and there is no definite
any of them give figures corresponding to the true weath
properties of the stone, except perhaps in regard to fro
omenon which may well be disregarded in Perth, where it
rare occurrence and of such slight intensity. None such
fore applied to these stones.

Long-continued brisk boiling, which might be expec
some idea of the resistance of the stone to the abraiding
wind and rain, gave results which were small and incon

(5) *Size of Grains and Porosity.*—As a rule a sto
unusually high percentage of coarse grains and but litt
and fine, or one with an overwhelming proportion of ve
but few grains of medium size, will wear less well than
posed largely of medium-sized grains with due proport
cementing material. The ideal condition would be such
of grains of various sizes that all pores are completely
Such a state is approached in the cases of the stones from
Government and Goldfields quarries, but more perfect co
this respect would have been indicated by still lower figu
porosity. As a key to the exact class of stone represen

crushing and other tests, the figures for the size of grain are invaluable when dealing with such a stone as sandstone which varies in texture within a small area.

The determination of porosity is important from several points of view, and is often incorrectly estimated. It is usually determined by finding the quantity of water required to fill up all the pores in a unit mass of rock. In this connection it must be remembered that mere immersion of a block of stone in cold water for a few hours or even a few days will not result in driving out all the air from the pores and substituting water for it. In the present case this result was attained by first standing the stone in shallow water and allowing this to be drawn up through the block by capillarity, then completely covering the block with water and alternately heating to boiling and cooling down until no further increase in weight occurred.

The figures obtained are important in determining the relative values of a series of stones for building purposes. A highly porous stone will absorb so much water as to make a building damp along exposed walls; further, it will allow of the free percolation of rain through the outer portions of blocks, thus accelerating disintegration. Again, the greater the pore space the larger must be the surface area of grains left uncemented to their fellows. Finally, the more porous a building stone is, the more rapidly the outer walls of a building in the City become discoloured by dust and smoke. All the Donnybrook stones compare somewhat unfavourably in respect of porosity with Sydney (Pyrmont), "Hawkesbury," and Stawell stone.

(6) *Chemical and Mineralogical Examination.*—The direct object of this section of the investigation was to determine what proportion of the whole stone is likely to be entirely unaffected by exposure to the natural elements, what proportion will slowly disintegrate, and what proportion will rapidly be affected.

Chemical analysis accompanied by examination under the microscope of rock powder and of thin slices of the rock (*see* Appendix) indicate that quartz, a practically indestructible mineral, forms quite three-quarters or more of the whole rock, occurring in grains of various sizes. Only to a slight extent does secondary silica occur as a cementing material, there being no unusually hard masses of silicified rock such as are present in several of the Victorian sandstones. Associated with the quartz is a fair proportion of felspar of two kinds, both of which are liable to soften, but at an extremely slow rate, on exposure. Of these the lime-soda felspars (oligoclase, etc.) are slightly less stable than the potash felspar (microcline).

The only other constituents in important proportions are kaolin (halloysite ?), limonite, and possibly talc. The first two are the important binding agents, whilst limonite or other iron hydrate is

responsible for the cream or brown colouring. Kaolin a
are not liable to chemical change except under the influ
sulphuric acid found in the atmospheres of busy ma
centres. Kaolin would soften appreciably on wetting un
well impregnated with secondary silica, a condition ap
the stones from the No. 1 and Government quarries.
are almost absent, as is also mica.

Two typical stones were selected for complete an
No. 10 from the No. 1 Quarry and No. 13 from the No.
The former is pure white on fresh fracture but slowly t
or light brown on exposure. The latter is light buff in
deep yellow stripes (secondary iron staining), and de
very slightly in colour on exposure. The results of analy
follow, analyses of typical Sydney and Victorian build
stones being quoted for comparison.

TABLE I.

*Analyses of Typical Australian Sandstones used for Buil
Purposes.*

—	Donnybrook.		Stawell, Victoria.	Egerton Victoria
	No. 1 Quarry.	No. 3 Quarry.		
Silica, insoluble ..	86·55	84·53	96·19	90·22
Silica, soluble (1) ..	1·38	4·73		
Alumina	5·83	5·82	1·90	7·56
Ferric oxide	·32	·50	·37	trace
Ferrous oxide ..	·10	·08	·06	*Nil*
Manganese oxide ..	*Nil*	*Nil*	..	trace
Magnesia	·76	·24	·09	trace
Lime	·21	·21	trace	trace
Soda	·56	·33	·04	·38
Potash..	2·58	2·18	·39	·22
Water at 100° ..	·47	·13	·11	·58
Water on ignition ..	1·01	1·28	·48	1·56
Carbonic acid ..	·02	·01	*Nil*	*Nil*
Phosphoric oxide ..	·17	·11	..	..
Titanium oxide ..	·14	·30	·10	..
Sulphuric oxide ..	·02	·03	..	..
Organic matter (2) ..	·04	*Nil*	..	..
	100·16	100·44	99·73	100·52
Analyst	H. Bowley.	H. Bowley.	P. G. W. Bayly.	H. C. Richard

(1.) *I.e.* soluble in Lunge's alkali solution after treating th
fuming sulphuric acid.

(2.) Calculated as humus from the carbon determined by wet

TABLE I.—*continued.*

—	Donnybrook.		Stawell, Victoria.	Egerton, Victoria.	Pyrmont, N.S.W.
	No. 1 Quarry.	No. 3 Quarry.			
Approximate Mineral Composition.					
Quartz..	70·85	74·84	92·63	79·27	79·46
Microcline	15·05	12·80	2·31	1·28	4·78
Oligoclase and Albite	4·73	2·91	·31	3·20	traces
Kaolin	5·43	7·23	3·60	16·94	12·95
Talc	2·28	·76	..	..	..
Limonite	·37	·56	..	..	..
Apatite	·37	·27	..	..	..
Ilmenite	·21	·17	..	..	..
Doelterite	·03	·26	..	..	..
Gypsum	·03	·05	..	..	.. (3)
Calcite	·04	·02	..	..	2·22
Organic matter ..	·04	*Nil*	..	..	..
Water	·47	·13	..	..	..
	100·00	100·00	98·85	100·69	99·41

(3.) Iron carbonate.

In the case of the other stones the chemical and mineralogical examination was restricted to the following five determinations:—

(a) A qualitative determination of the minerals present as shown by the microscope in a thin slice. This showed that all the stones were of the same type of felspathic sandstone.

(b) Total insoluble in fuming sulphuric acid. This represents the total proportion of the stone which may be taken for all practical purposes to be absolutely resistant to any chemical change on exposure to the atmosphere. In every case it was approximately 95 per cent., a figure higher than any Sydney sandstone of which I have data, but approximately the same as in that from Stawell, Victoria.

(c) Carbonic acid. This indicates the proportion of carbonates present. These, in conjunction with clay, form one of the strongest of all binding materials, but not resistant to acid vapours. The Sydney and Hawkesbury stones owe their strength mainly to this combination of clay and carbonates. The Donnybrook stones are practically devoid of carbonates, but in those from the Government and No. 1 Quarries their place is filled by secondary silica, a still stronger and more durable cementing material.

(d) Acid-soluble Alumina.—This gives an indication of the relative proportions of clay; the percentage of the latter being approximately equal to the percentage of soluble alumina multiplied by two and a half.

(e) Acid-soluble Iron oxide.—This is a useful binding
The presence of iron in a light-coloured stone such as Don
No. 1 or Pyrmont indicates the certain darkening of the s
exposure, an important matter from an aesthetic standpoi

(7) *Colour, Evenness of Appearance, etc.*—These ar
worthy from an aesthetic point of view, and normally sh
determined before and after weathering. In the absence of
ing tests, note is made of the amount of iron in the stone,
any change of colour on gentle heating to about 200deg. C.

Any visible unevenness in grain or texture is a seriou
back, as it will almost certainly lead to uneven weathering.

Cross-bedding (current bedding) is a serious source o
ness in a sandstone, as are also clay partings. Neither was
in the specimen blocks of Donnybrook stone, nor, with on
tion, in any City buildings, though Mr. H. P. Woodward,
recently visited Donnybrook, informs me that confused be
the cause for rejecting a considerable amount of stone at
the quarries. The streaky colour scheme not uncommonly
blocks from Vincent's and the No. 3 Quarries is not an in
of cross-bedding, but is merely due to irregular distribution
amounts of iron oxides which in most cases have penetra
the stone from overlying laterite. It is not parallel to an
tural lines of parting or weakness.

Another frequent defect in sandstones is the presence
pockets of softer, incompletely cemented sand grains, "san
These should be detected by hand and eye during working
allowed to appear on the outer surface of a building. Th
frequent in Donnybrook stone and not observed at all in an
specimen blocks submitted, they are to be seen in several b
the stone in City buildings.

Visual inspection should disclose if any organic debris
sent in sufficient amount to cause local weakness. None
served in any Donnybrook stone. The "organic matter" s
the analysis of the stone from the No. 1 Quarry is very ev
tributed through the stone, probably in the form of an
compound of iron, which is colourless in the natural s
darkens on heating or exposure to the weather.

Results of Tests of Individual Stones.—The accom
Table II. gives the numerical results of the tests applie
different stones. The inferences drawn from them and f
inspection of local buildings are given in the following no

No. 1 Quarry (Alexander's).—North end of Loc. 124
Donnybrook. The stone from this quarry is pure white i
when fresh, and finer in grain than any other in the series e

Moderate heating (200deg. C.) changes the colour to dark grey, and exposure to the air even under cover produces a decided cream tinge on the surface in about twelve months. An inspection of the buildings in which it has been used shows that it somewhat rapidly darkens to a light to medium brown colour on exposure, giving a very agreeable appearance of age to the structures. The specimen blocks show no cross-bedding, sand balls, or unevenness in grain, though this latter is marked in some few blocks in local buildings. It is composed mainly of quartz grains with about one-quarter the amount of felspar grains, the cementing material being clay with a little secondary silica, a strong combination when in sufficient quantity, as appears to be the case with this stone. The figures given by the crushing test (490-542 tons per square foot) place it amongst the best freestones the world over. The chief defect of this stone is its porosity, which is double that of average Sydney stone, and three times that of typical Stawell stone. Its absorption of water is, however, well within the limit laid down for best building brick (10-12 per cent.), and so far as I have been able to ascertain it has not caused dampness in the buildings in which it has been used, nor has it led to a noticeable amount of surface fretting. This stone is entirely devoid of those extremely hard patches of secondary silica which are the chief drawback to the use of Stawell stone. It carves well, taking a fine edge, and is capable of any sort of finish short of a polished surface.

An inspection of the Art Gallery and Technical School indicates that all originally sound blocks have maintained their sharp outlines and the surface is everywhere in a sound, hard, even condition. Some blocks in both buildings were evidently originally faulty from the presence of "sand balls" or confused bedding and should never have been put into the face of the buildings.

All things considered, this is an excellent stone for building purposes, though slightly expensive to work, a natural result of its superior hardness and durability. Attempts are being made to put on the market grindstones cut from this stone.

No. 2 Quarry (Alexander's).—Near centre of Loc. 1244, North Donnybrook. No specimen blocks from this quarry have been subject to investigation in the Geological Survey Laboratory. The stone has been used for portions of the Telephone Exchange in Murray Street, Perth, where it can be seen to be a stone closely resembling that from the No. 1 Quarry. It is uniformly fine grained, white on a fresh fracture, but somewhat darkened by exposure. It is a hard stone capable of a fine finish. There are no signs of fretting, and the arrises are still sharp after several years' exposure. Several of the blocks are disfigured by sandballs. In the absence of experimental data, it is inadvisable to express a definite opinion of this stone.

Vincent's Quarry.—South end of Loc. 1244, North Donnybrook. No investigations have been made in this Laboratory of the stone from this quarry, which was one of the first to be opened in the district. The stone from it used in the basement of the Supreme Court, Perth, is much coarser and more irregular in grain than that from No. 1 or No. 2 Quarry. It is fairly hard and shows no signs of deterioration after thirteen years' exposure, but is not capable, apparently, of a very fine finish. The chief defect in the fresh stone was its great irregularity of colour, the stone being variously ironstained in streaks and blotches of crude yellow and brown tints. Weathering has darkened the background and obliterated this effect to a large extent on the outer walls, though the appearance is still not very pleasing except perhaps under the arcade on the south front, where the stone now has a rich yellow ground with lines of deeper yellow not unlike wood graining.

Government Quarry (Arnott's No. 2).—Reserve 2720, North Donnybrook. This quarry is furnishing the stone now being used in the upper portions of the east front of the new General Post Office, Perth. It is a stone similar in appearance and equal in quality to that derived from the No. 1 Quarry. It is mostly pure white in colour with rarely creamy or light brown inconspicuous blotches or stains. On exposure the white stone will doubtless darken somewhat in colour since, like the No. 1 Quarry stone, it contains iron compounds and darkens distinctly on heating to 200deg. C. The grain is very fine and even, and the stone as a whole is dense, tough, and hard. It works excellently by machine or by hand, and is well suited for fine carving. The Chief Architect informs me that it is singularly free from sandballs, and personal inspection shows its freedom from quartzitic patches or other appreciable variations in texture. The grains are quartz with a fair amount of felspar, whilst the binding material is essentially kaolin with traces of secondary silica. Crushing tests have given results equal to those of the stone from No. 1 Quarry, viz., 418 to 597 tons per square foot.

No. 3 Quarry.—North-east corner of Loc. 48/1924, North Donnybrook. The specimen stone from this quarry is distinctly inferior to those from the No. 1, Government, and Goldfields Quarries, having a much lower compressive strength, and much greater porosity. It is somewhat fine grained, and consists mainly of quartz grains with some felspar grains and a clay cement. The uneven iron-staining of the new rock is a slight disadvantage. This stone is moderately soft and in consequence works easily.

Stone from this quarry has been extensively used in Perth, and in the Police Courts has undergone exposure for twelve years. At present in this building all arrises above the reach of heavy traffic are quite sharp and unbroken, nor is there any sign of surface fretting, or of flaking or splitting. Even close to the pavement in a busy street the arrises are but little chipped or worn. Despite its high porosity, no signs of damp are to be discovered inside the building. This is evidently a very satisfactory building stone. It does not apparently darken greatly on exposure. Further, either the quarry yields but few faulty blocks, or these have been kept out of the building by careful inspection during erection. Two of the largest buildings in Perth, viz. the Australian Mutual Provident Society's offices and St. George's House (Millars' Timber and Trading Co.), were built of this stone. Sand balls are not uncommon in the stone used in the latter, and in both small circular dark brown iron-stains have developed on exposure; they are, however, inconspicuous except on close scrutiny.

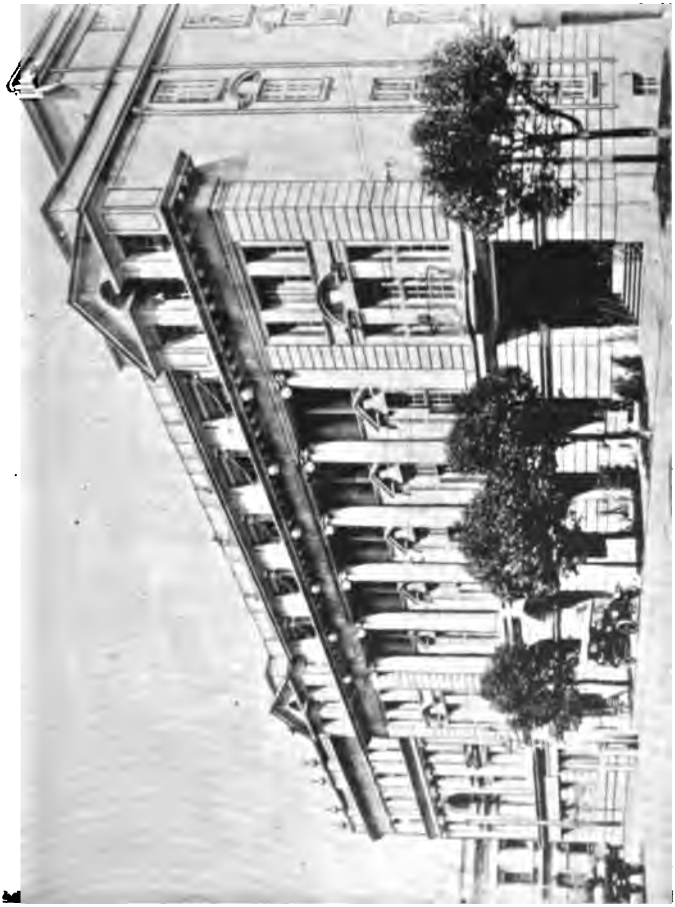


Fig. 9.

St. George's House, Perth. Facade of stone from No. 3 Quarry, North Donnybrook.

Armstrong's Outcrop.—South-west corner of Loc. 15 Donnybrook. This yields a medium-grained stone of creamy colour with white mottling. It bears considerab blance in grain, porosity, etc., to the stone from No. 3 Qu which it compares favourably when dry. Tests show, how it loses seriously in coherence when wetted. Wet crushin it are badly needed. This stone has not been used in any in Perth, so that exact data with regard to its durability ing. On purely laboratory figures I am inclined to consi be inferior to those previously described, and unsuited portant public buildings.

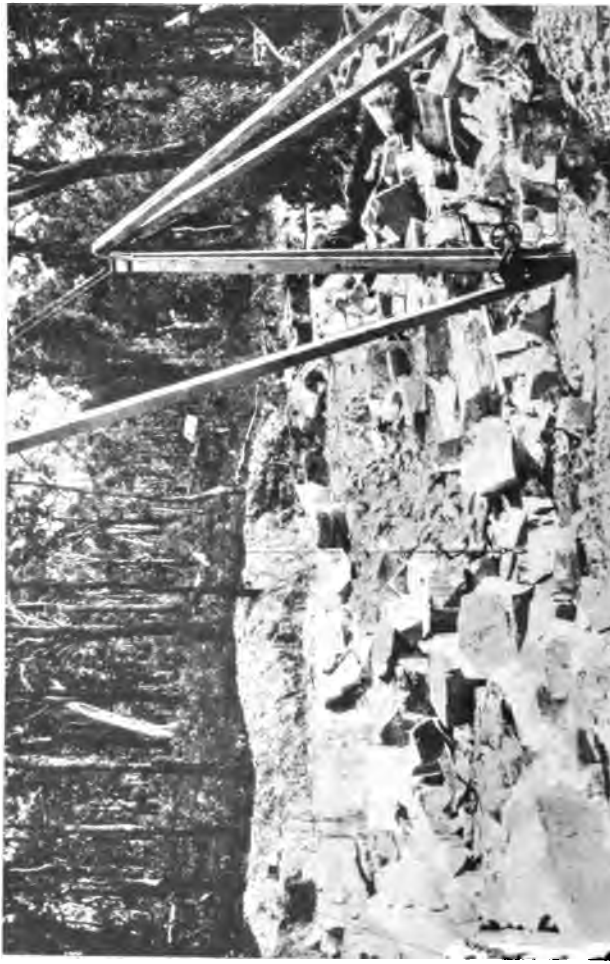


Fig. 10.

Arnott's No. 1 Quarry.—North-east corner of Loc. 48/1991, North Donnybrook. This small quarry yielded stone of very irregular grain and coloration. A small quantity has been used in one part of the basement of the new General Post Office on the south side, where it is seen to be a light-coloured stone with irregular iron-staining and uneven and confused texture, such as might be caused by violent eddies in the current during the deposition of the sand grains.

Goldfields Quarry.—West side of Crendon Road, on old Gold Mining Lease 66, South Donnybrook. This stone is the heaviest and coarsest grained of the series, and is also less porous than that from any other Donnybrook quarry. It is from deep to light buff in colour, and is devoid of cross-bedding or irregularity in grain. The grains are mainly quartz with a little felspar, the cementing material being clay with a little secondary silica. It is somewhat inferior in crushing strength to the stone from the No. 1 and Government Quarries, but I am of opinion that it would not be much, if at all, inferior to these in durability. It would doubtless be cheaper to dress, though incapable of yielding such sharp outlines as the other two mentioned.

One of the few places in which this has been used is in the lower portion of the facade of the Government Stores Office. An examination of this, which has been exposed for about six years, shows so far no sign of any defects other than a few apparently original ones in isolated blocks. Some of the stones in this building are plainly finer grained than the average. In view of its superior density and lower porosity, this stone is worthy of further application in local buildings devoid of fine detail.

Pink Quarry.—North of Loc. 48/1316, South Donnybrook. Two different classes of stone were submitted from this quarry, one from the surface, the other from a depth of eight feet. The latter when freshly quarried possesses a very handsome appearance, being of a rich pink colour which is evenly distributed. This colour, being due to fully oxidised compounds, is likely to be permanent over a long period of time. Small black blotches due to a local concentration of oxide of iron present a marked blemish when close to the eye, but at a slight distance are invisible, and would have no effect upon the general appearance of a building. Similar blotches have developed in stone from No. 3 Quarry (*vide supra*). Unfortunately, though possessing a moderately high compressive strength when dry, on soaking with water it loses the greater part of its coherence. This condemns it completely for outside work in a building of any importance. Owing to its beauty it might well be given a trial in some small building where its failure would not cause any serious loss.

The stone from the surface resembles the previous colour, but is distinctly bedded, with large variation in in the different thin layers (*vide* figures in Table II.). from a depth of eight feet, it loses most of its coherence o and must be looked upon as valueless for outside work.

Original, 19th March, 1915.

Revised, 30th December, 1916.

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		Analysis.			
der 0 sh.	Relative Coarseness (3).	Total Insoluble.	Soluble Alumina.	Soluble Iron Oxide.	Carbon dioxide.
·7	414	94·04	2·33	1·79	0·01
·2	370	95·07	2·85	0·50	0·02
·3	186	94·86	2·91	0·35	*Nil*
·4	182	95·25	2·53	0·38	0·01
·	..	..	..	..	..
·7	327	94·52	3·26	0·59	0·02
·0	207	..	..	..	..
·2	274	..	..	..	..
·7	199	94·76	2·36	0·98	0·01
·	..	..	..	..	..
·1	293	94·77	2·22	1·9	0·03
·	..	..	..	..	..
·2	316	93·57	3·94	0·43	0·01
·3	260	94·88	3·35	0·35	*Nil*
·	..	..	..	..	..
·0	371	87·71	5·54	2·68	0·90
·	..	(4) 85·45	(5) 7·60	2·12	1·09
·	..	(4) 96·19	(5) 1·90	0·44	*Nil*

rains over 30 mesh by 7 ; that over 60 mesh by 5 ;
(4) Total silica. (5) Total alumina.

UNIV OF

TABLE III.

incipal Structures in which Donnybrook Stone has been used.

ry.	Town.	Building.	Date completed.
.	Fremantle ..	Railway Station ..	..
..	do. ..	Customs House	1908
..	do. ..	St. John's Church, Tower and Spire	..
..	Perth	Art Gallery	1908
..	do. ..	Technical School.. ..	1910
..	Midland ..	Court House	1907
..	Bunbury ..	Court House	1907
..	Perth	Telephone Exchange ..	1913
..	Fremantle ..	Technical School.. ..	..
..	Perth	Police Courts	1905
..	do. ..	Haynes, Robinson, and Cox's	1906
..	do. ..	Public Health Department	1911
..	do. ..	Parliament House, Central portion, west front	..
..	do. ..	Public Library	1913
..	do. ..	St. George's House ..	1914
..	do. ..	A.M.P. Buildings ..	1914
..	do. ..	Dalgety's	1915
..	do. ..	Levi Green's	..
..	East Guildford	Chapel of S.S. Mary and George	1914
..	Collie	Court House	1913
s ..	Perth	Government Stores ..	1911
..	do. ..	Government Analyst's Office	1904
..	Perth	Supreme Court	1903
..	Claremont ..	Training College ..	1902
ent..	Perth	New General Post Office	Under construction.

APPENDIX I.

PETROLOGICAL EXAMINATION OF SIX SAMPLES OF BUILDING STONES FROM DONNYBROOK.

BY R. A. FARQUHARSON.

The difficulty in sectioning these having been overcome, examination of the slides has given the following results:—

> The rocks are all essentially similar in structure, composition, and physical character. The mineral composition is in brief: quartz, felspar, kaolin and some iron staining. No pyritic ore, and no mica was observed. In general character they are all somewhat incoherent and friable felspathic sandstones or grits, the compactness of which is more due to pressure than to the presence of cementing material such as secondary quartz or iron oxides. The cementing material is in very small part secondary quartz and in part (in some of the specimens) oxide of iron, but both are but poorly developed. The majority is of an argillaceous (kaolinic) nature.

As building stones the samples will be easily dressed and in spite of the argillaceous nature of the cement and the comparative absence of resilicification should, under normal conditions, wear reasonably well, though not so well as resilicified sandstones.

Following are descriptions of the samples:—

[**13934**] (S2456) No. 10.—No 1 Quarry. A very fine-grained white gritty rock, slightly friable, but more compact than the rest of the specimens.

In section, the minerals are quartz grains and felspar grains, rounded and angular with very little cementing material. The latter appears in places to be secondary quartz, but most of the material between the grains—and there is very little of it—is opaque, granular and white, with argillaceous (kaolinic) characters. Some of the quartz grains are cracked and enclose indeterminable hair-like inclusions, while some irregular extinction is noticeable in them.

The rock is a partially compacted *Felspathic Sandstone* of somewhat friable nature, and of very fine grain.

[**13933**] (S2454) No. 13.—No 3 Quarry. A slightly coarse gritty rock banded alternately yellowish-brown and yellowish-white and somewhat friable.

The rock is again composed of rounded and angular quartz grains and felspar grains, with a yellowish-brown clayey cement. The felspar is in places microcline, in places too much kaolinised for determination. No secondary silicification was observed. The banding is due to limonitic staining.

The rock is a friable banded *Felspathic Sandstone* or *Grit*.

[**13931**] (S2452) No. 22.—Armstrong's Outcrop. A fine-grained, pinkish, granular rock quite friable and hence easily dressed, but liable to fretting, and consisting of quartz grains and minute white particles with occasional reddish spots.

In section, the bulk of the rock is made up of small rounded, as well as more or less angular quartz grains—occasionally showing strain shadows—less common grains of felspar which are frequently kaolinised to complete turbidity and which include microcline and orthoclase as well as twinned plagioclase, and occasional small dusty red patches of material that is probably iron-stained kaolin.

Cementing material is present only in small amount as a thin film between the quartz grains, and appears to be of argillaceous (kaolinic) nature.

Secondary silica as cement is very poorly if at all developed. In consequence, there is some slight lack of coherence in the rock and its friability is noticeable.

The rock is a fine-grained *Felspathic Sandstone*, formed by compacting of grains of quartz and kaolinised felspar by pressure without the production of much secondary silica as a cement, or the introduction of such binding material as oxides of iron.

[**13935**] (S2457) No. 5.—Goldfields Quarry. A slightly coarser-grained yellowish, and somewhat friable gritty rock, very similar to the above.

The composition is the same as in No. 22, *i.e.*, rounded and angular quartz grains and occasional kaolinised felspar grains with cementing material as before. The structure, however, is again rather loose and incoherent. Iron staining is almost entirely absent.

The rock is a *Felspathic Sandstone* or *Grit.*

[**13932**] (S2455) No. 16.—Pink Quarry. A fine-grained, reddish-pink, granular, gritty, and friable rock, with grains of quartz, whitish specks, and reddish grains.

In section there are small quartz grains mostly, but subsidiary kaolinised felspar grains and slight iron staining are also visible. Cementing material is again not conspicuous, but there appears to be a slight development of secondary silica between some of the quartz grains. The structure of the rock is again somewhat loose and incoherent, due to the comparative lack of development of cementing material.

The rock is a somewhat friable felspathic sandstone in which the coherence is due in part to compacting by pressure, in part to secondary silicification, and in part to an argillaceous (kaolinic) cement.

[**13930**] (S2451) No. 18.—Pink Quarry. In all respects is essentially similar to No. 16, with slightly deeper iron staining.

10th November, 1914.

68.—THE KENDENUP GRAPHITE DEPOSITS—SOUTH-WEST DIVISION.

By H. P. Woodward and T. Blatchford.

(With two Figures.)

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Historical.

Although the existence of these deposits has been known for over 50 years, and that at least upon three occasions attempts have been made to work them, owing to the low grade of the material discovered they were each time abandoned after a short trial. In 1903 a syndicate was formed to further test them, when the work carried out revealed the presence of some much higher grade ore, but owing to the fact that funds were difficult to obtain little mining development of a systematic character has been executed, although work in a more or less desultory manner has been conducted for a period of years.

Situation.

The area in which these deposits exist is situated close to the Great Southern Railway line at a distance of 290 miles from Perth and 50 miles from Albany, the nearest port of shipment.

Physiographic Geology.

The deposits are situated on the banks of the Kalgan River, which at this point follow an east and west course along a valley, which is about 500 feet above the sea-level. This valley lies between the Stirling Range to the northward and the Mt. Barker-Porongorup Range to the southward. The surface level rises gradually along the course traversed by the railway line some 450 feet in a northerly direction to Tenterden, which is 14 miles distant, and 300 feet southward to Mt. Barker, which is eight miles away.

The Stirling Range is a bold mountain mass which runs in an east and west direction for a distance of about 40 miles, and in it the main peaks attain an elevation of close on 4,000 feet. This range consists of stratified rocks (mostly quartzite), the geological age of which has not as yet been determined owing to the absence of organic remains and other difficulties of correlation. It would at one time appear to have formed a portion of a chain of mountains which extended from Phillips River on the east, at least as far as the Gordon River, though, in latter portion the rocks are, however, of a more highly metamorphic character.

On the south side of the Kalgan valley there is a distant change in the character of the rocks. These form a broad strip along the south coast from Cape Riche to Point d'Entrecasteaux, and also makes its appearance westward of the Darling fault at Cape Leeuwin.

In this valley, which lies between the two range lines, beds which contain marine fossils referable to the Tertiary Period are met with a few miles to the eastward of the railway line and extend from that point to Cape Riche, thus proving that at no very remote period it was submerged.

From the foregoing it will be apparent that this valley has been formed by marine and fluvatile agencies along a shear zone which exists at the contact of the igneous and metamorphic rocks, and that this is of probably considerable extent, which, being the case, further graphite deposits may be discovered along it in both an east and west direction, while those situated on the Donnelly River and at Big Brook, which lie due west, may also prove to be situated in the same zone.

So far as can at present be determined from the meagre evidence afforded by the highly weathered and altered rock specimens available, it appears that the rock formations in which this valley has been cut are composed of highly metamorphosed and sheared ancient sediments which have been tilted at a high angle, and further, that the graphite deposits which always occur in a bedlike form result from the crystallisation of beds rich in carbonaceous matter.

GENERAL.

Graphite in commercial quantities was first found on Plantagenet Location No. 27, at a spot about a mile distant from the Kendenup Homestead, and on the south side of the Kalgan River.

Since this discovery traces of the mineral have been found on Location No. 12, to the east of the Great Southern Railway, between the 48- and 49-mile posts, the mileage being that from the port of Albany.

Also, traces have been reported to the west at Mollyalup Lake, but such were not located by the writer, though there seems no reason to doubt that traces were found in this locality. The geology of the area is difficult to translate, as the surface is for the most part covered over with recent superficial deposits, and outcrops of the underlying rocks are rare, and do not exist at all to the south of the Kalgan River. North of the river granite outcrops, and it would appear that the river marks the junction of granite and sedimentary rocks, with the graphite occurring in the latter rock. Unfortunately, the nature of these sedimentary rocks could not in any instance be investigated with accuracy, as it is doubtful whether the unaltered forms outcrop at all, and in the mine workings the weathering extends below the deepest level yet reached and, in consequence, masks the characteristics necessary for definite classification.

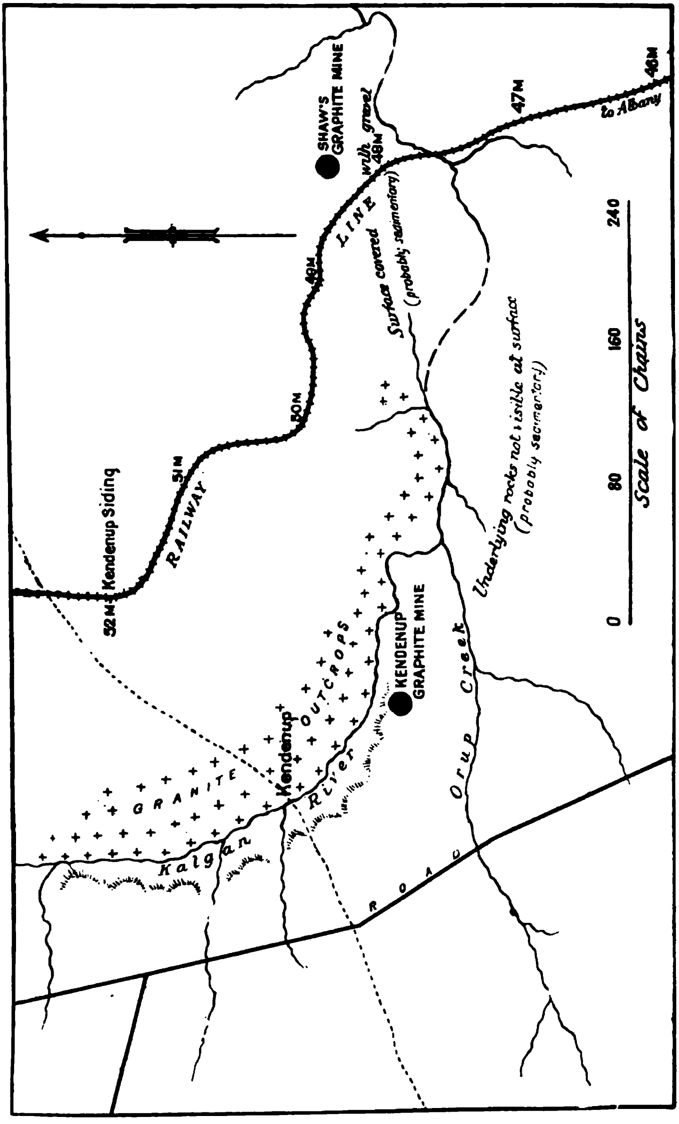
The general features, however, would lead one to suggest a sedimentary origin, and there is every likelihood, in the writer's opinion, that the rocks represent much weathered schists, shales, or allied sedimentary beds.

Kendenup Graphite Mine.—The accompanying plan (Plate VIII.) shows the extent of the workings of this deposit, with the exception of a few minor ones at the surface, since fallen in and inaccessible.

From the main shaft, at a vertical depth of 50 feet, a drive west 20 feet in length passed through soft ground, throughout which were grains of scaly crystalline graphite. A sample taken across the back of the drive, about midway between shaft and end, yielded at the hands of the departmental Chemist 12.10 per cent. graphite.

From the same level a drive was put in eastward for a distance of 38 feet. Towards the end this drive was diverted to the north, and in consequence resolved itself into half-drive and partly crosscut. At the extreme end of the drive a hard siliceous band was encountered, the thickness of which was not determined. A sample of this siliceous rock was submitted to the Petrologist, who, on microscopic inspection, is definite in his decision that the rock represents a much crushed quartzite, throughout which are innumerable small specks of graphite. Felspar is wholly absent, and the quartz veins show stress figures and uniform fracturing, evidences of strains induced in the rock since it was originally formed. From here on the drive was diverted to the east and continued for a distance of 20 feet, the hard band being on the north side of the drive. This portion of the workings could not be inspected personally owing to the fact that the whole of the drive had caved in and was completely filled.

Fig. 11.



Geological Sketch Map showing the location of the Kendenup Graphite Deposit.

Starting from the shaft, one can readily see the increase in the graphite contents as the quartzite is approached, until, lying up against the quartzite itself, extremely rich seams of the mineral are exposed. This is also borne out by a comparison of the rough samples taken, the value in percentage of graphite increasing in direct ratio with proximity to the quartzite band.

The mineral occurs for the most part in isolated scales, the long axes of which appear to run parallel to an indistinct foliation striking approximately east and west, and is fairly uniformly distributed. When the quartzite band previously referred to is approached, these scales are seen to increase in number and occur both in lenses and seams or veins in which the proportion of graphite exceeds that of the gangue, a picked sample yielding as high as 80.54 per cent. of the mineral.

The full extent of this enrichment was hidden from inspection owing to the caving in of the workings, and it is unfortunate for all parties concerned that the mining has been carried on in such an unsystematic manner. With proper mining equipment and at small expense the deposit could easily be developed to a depth of probably 100 feet, for the water is negligible to a vertical depth of 60 feet, and the ground, though heavy in places, is not "difficult" ground.

On the other hand, the deposit gives promise of paying its way from mineral won in development, for there should be considerable quantities of ore available, by hand-picking only, which would yield 60 per cent. graphite contents, a distinctly marketable and profitable product.

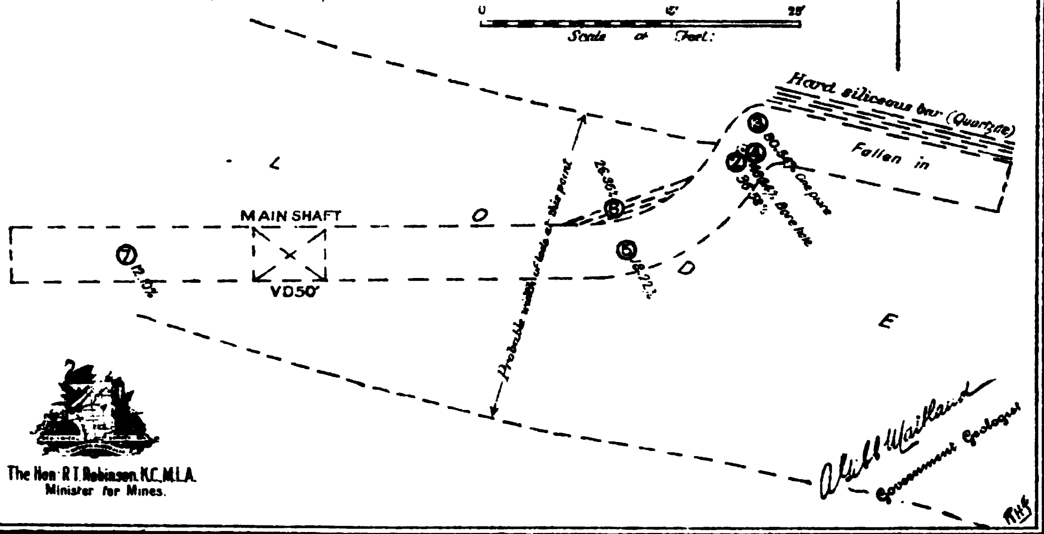
Shaw's Mine.—This property is situated almost due east from Kendenup (*vide* plan), and lies about 400 yards east of the 48¼-mile post of the railway line. At the time of my inspection there was practically nothing to be seen except one shaft, which had been sunk to a vertical depth of 25 feet. The rock pierced in this shaft was a much weathered clay in which occurred numerous ironstone nodules. Traces of graphite in the form of minute specks and occasional small nodules indicated the presence of the mineral. A sample from the bottom of the shaft yielded 6.57 per cent. of graphite. The coarse mineral here is more in the form of plates than scales, and not uncommonly it is seen to be very fine in texture too. It does not assume the uniform scaly form of the Kendenup deposit.

Outcrops of the underlying rocks do not occur in the vicinity, and until a greater depth in sinking is attained the nature of the rock will be undeterminable with any degree of accuracy, though in all probability it will be found to be a continuation of the same country as that in which the Kendenup deposit occurs.

The only other place in which graphite was detected was in the mud banks of the Kalgan River, between Kendenup Homestead and the mine of that name.

SKETCH PLAN
OF
THE KENDENUP GRAPHITE MINE
S.TH W. DIVISION.
BY
T. Blatchford, Assistant Geologist.

Showing Main Workings, where samples were taken and results.



A. Gibb Maitland
Government Geologist

H. J. Pether, Government Lithographer, Perth, W.A.

Here a sample of the ordinary swamp mud was taken, and on drying, distinct grains of the crystalline mineral could be seen when examined under a microscope.

The graphite contents on chemical analysis proved to be 1.57 per cent.

This trace of graphite is important, as it tends to prove the existence of graphite other than in the Kendenup mine, for the spot where the sample was taken was above the mine, and the mineral could not possibly have come from that source unless the lode extended fully half a mile westward. It would be interesting to take samples further up the river to see how far these traces extend and thus, may be, locate their origin.

In addition to the samples of the crude ore, two samples were also taken of the concentrates bagged for shipping.

These yielded 46.63 per cent. and 54.38 per cent. graphite.

The concentration has been carried out in an experimental plant by first putting the ore in small vortex mixers and allowing the whole to flow on to a shaking screen with three compartments: the flow is into the centre compartment. In practice, the fine argillaceous gangue is supposed to pass through the screen, whilst the flaky graphite is supposed to dash out of the centre compartment into the two end ones and thereby form a concentrate. Unfortunately, it appears to have a reverse action, the fine graphite passing through the screen and the gritty gangue remaining on top. Certainly the concentrates do not exceed some of the crude ore in graphite contents. One of the reasons for this apparent mistake is the deceptive appearance of the size of the graphite scales, which appear on first sight to be much larger than they are, whereas probably 90 per cent. will pass a 40 mesh (1,600 holes to a square inch). In developing the mine, the writer would strongly recommend a system of mining whereby the richer or northern side of the lode would be opened out, and until the deposit was exploited sufficiently to warrant a proper concentrating plant, let hand-picking and shipping the crude high-grade ore be resorted to. The deposit should be well worthy of such treatment.

APPENDIX I.

Table of Proximate Analyses of Graphite from the Kendenup Deposits, made in the Geological Survey Laboratory by H. Bowley.

G.S.L. No.	9248.	9249.	9250.	9251.	9252.
Mark	1	2	3	4	5
Moisture	2·99	2·26	·49	3·63	2·96
Volatile matter *	9·63	2·40	1·49	4·55	3·94
Graphite	6·57	36·58	80·54	18·22	46·24
Ash	80·81	58·76	17·48	73·60	46·86
Total	100·00	100·00	100·00	100·00	100·00
Colour of Ash	Brown.	Light Brown.	Buff.	Brown.	Light Brown.
Fusibility of Ash †	Infusible.	Infusible.	Infusible.	Infusible.	Semi-fused.

G.S.L. No.	9253.	9254.	9255.	9256.	9257.
Mark	6	7	8	9	10
Moisture	4·24	3·26	2·68	3·88	8·66
Volatile matter *	2·11	12·59	3·83	4·74	13·82
Graphite	26·86	12·10	54·38	46·63	1·57
Ash	66·79	72·05	39·11	44·75	75·95
Total	100·00	100·00	100·00	100·00	100·00
Colour of Ash	Brown.	Brown.	Brown.	Brown.	Light Brown.
Fusibility of Ash	Semi-fused.	Infusible.	Infusible.	Infusible.	Infusible.

* Mostly water.

† On ignition by an air-coal gas blast in a platinum crucible.

2nd August, 1916.

DESCRIPTION.

No.		Per cent. Graphite.
1	Taken from bottom of Shaw's Shaft	6·57
2	Taken at east end of drive six feet from face, across back of drive	36·58
3	Picked sample from one of the veins	80·54
4	Sample across back of drive about 15 feet from face	18·22
5	Bore-hole slightly inclined to the North, about six feet deep..	46·24
6	Sample, continuation of No. 5 into North Wall—where broken down	26·86
7	Sample from back of West drive, about 12 feet West of shaft	12·10
8	Shipping sample, 1st grade	54·38
9	Shipping sample, 2nd grade	46·63
10	Sample of alluvial in Kalgan River banks	1·57

APPENDIX II.

'etrological Notes on the Graphite Ore and character of the Flakes from Kendenup.

In the low-grade samples the ore is of a dirty reddish colour due to the esence of a considerable amount of disseminated earthy iron oxide. The aterial has a roughly banded or laminated structure with frequent lenticles thin bands of quartz and quartzite. The graphite itself occurs in small folia booklets of aggregated scales as well as in confused scaly masses in the clayey itty and ferruginous laminated gangue. The graphite laminae or scales are ranged generally with their flat surfaces parallel to the imperfect banding or nination. Samples have been found which show a diminution in the amount iron oxide and also of gritty quartz, but the presence of a considerable nount of a canary or greenish-yellow material in small masses, which is rered to nontronite, the hydrous iron silicate. The presence of this mineral ggests that the graphitic deposit has been produced rather by dynamic etamorphism of carbonaceous sediments, than by igneous emanations. A le granular granite is also present. Samples of a fairly high degree of purity to 80 per cent—show but a low development of grit or earthy iron oxide. e ore in these cases has a laminated schistose or shear structure, with the kes (or flaky aggregates) elongated along the planes of schistosity. These nples are dark lead-grey in colour and very friable. Interleaved mica was t observed in any sample. The character of the graphite is scaly crystalline, t the size of the scales is very deceptive. The refined product in bulk apars quite coarsely scaly with the individuals about the size of a pin-head or nillimetre in diameter. Examination, however, shows that these apparently ge scales are undoubtedly scaly aggregates : the maximum size of scale served did not much exceed half millimetre in diameter, *i.e.*, about 1/50th an inch to 1/40 of an inch, whilst the vast majority of the scales varied in e from 1/50th of an inch to mere specks. So far as could be seen, however, were crystalline, though determination of the crystalline or amorphous racter of minute specks is very difficult.

R. A. FARQUHARSON,
Petrologist.

1st August, 1916.

69.—THE GEOLOGY OF THE WATER RESERVE FIND AT LINDEN, NORTH-EAST COOLGARDIE GOLDFIELD.

(C. S. Honman.)

WITH ONE FIGURE.

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Situation.

The main open-cut from which the crushing was taken by Messrs. Love & Lowe is situated in the Water Reserve, 25 chains north-east of the tank, and on the east side of the main watercourse leading to the tank. The tank is 128 chains 24° east of south of the Mt. Linden Trigonometrical Station W 8.

Geology.

The rocks occurring in the locality are fine-grained greenstones and ferruginous quartzites intruded by granite and porphyry. The greenstones are schistose, even having an incipient schistosity developed where they are more massive. In the vicinity of Love & Lowe's open-cut the greenstone schist strikes 13° east of north, and the porphyry dykes 45° east of north. Massive granite occurs five chains south of the open-cut, and half a mile to the east a large granite belt abuts the greenstone. Numerous porphyry dykes intrude the greenstones in the vicinity. The greenstone is probably a transmuted doleritic basalt. Evidence of volcanic origin occurs in many places, such as distinct vesicular structure and presence of interbedded agglomerate schists. One band of the agglomerate schist occurs west of the open-cut.

MINING GEOLOGY.

The gold occurs in a "lode formation" which resembles those at Kalgoorlie, possessing the most important characteristics of such, viz.:—

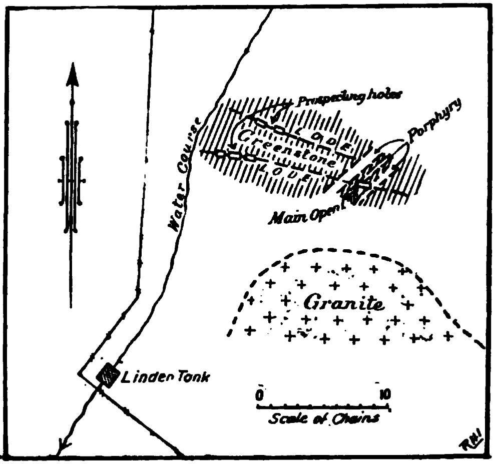
(1) Indefinite walls. Limits of the "lode formation" only determinable by the dish prospects.

(2) Presence of "greasy heads" or planes of parting in lode. The best gold values are associated with these heads.

(3) The strike of the lode formation crosses the strike of the country.

(4) Extensive impregnations by carbonates.

Fig. 12.



Geological Sketch Plan of Workings in the Water Supply Reserve, Linden.

The "lode formation" strikes between 70° and 80° west of north and almost at right angles to the greenstones, which are frequently cut by porphyry dykes. The lode apparently persists through the porphyry, as gold occurs in the porphyry on the line of strike of the lode. The experience at Kalgoorlie is that lodes are impoverished where they occur in porphyry.

The "lode formation" is practically vertical, being associated with "planes of parting" or "greasy heads" in proximity to which small quartz veinlets occur.

A crushing taken out from an average width of three feet gave a return of 1 oz. per ton from a parcel of 30 tons. Considering the unoxidised nature of the country this is most favourable, since the gold is probably all primary.

The "lode formation" cannot be followed on the surface except by dish prospects. The cap of the lode does not differ in appearance from the surrounding country rock. When opened up, the only other indication apart from dish prospects is the "greasy heads."

Nine chains distant from the open-cut on a bearing of 282°, and on the strike of the lode, a similar formation has been opened up having the same strike. There is no indication of the presence of the lode on the surface between these two points, except that gold prospects have been obtained at intervals on the line of strike.

Three chains east of the main lode a similar formation has been opened up striking parallel, but on this not much work has been done.

All the work has been done on the central prospecting area held by Messrs. Love & Lowe.

In conclusion, I am of opinion that this find is an important discovery, and that no hindrance should be put in the way of its being thoroughly prospected for two main reasons:—

(1) Resemblance to the "lode formation" of Kalgoorlie.

(2) Occurrence in a promising mining centre, Linden, and in a district in which similar geological conditions are wide-spread.

The experience is that this type of lode lives to the greatest depth that mining has attained in Western Australia.

It must be borne in mind that the find is totally undeveloped, and that the lode may be greatly interfered with by porphyry dykes, and possibly by granite at depth.

13th December, 1916.

0.—THE CLAY DEPOSIT AT NEWLANDS, SOUTH-WEST DIVISION.

H. P. Woodward.

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OCALITY.

This deposit is exposed in a cutting upon the Bunbury-Bridge-
own railway line about one mile due north of the Newlands Rail-
ay Station, the exact locality being on the boundary of locations
os. 6 and 7 of the Preston Agricultural Area. The cutting referred
is situated at the top of a steep gradient about 22 chains in length
nd 36 feet deep at its centre.

HARACTER.

The rock exposed in this cutting consists for the most part of
gritty clay, but near the centre of the cutting a kaolinitic clay
ale deposit is exposed beneath it for a length of five chains, rising
the section to a height of 12 feet.

This shale is divided from the sandy clay by a lateritic layer
hich often contains pebbles of rock and quartz fragments clearly
epresenting an old surface, while from this downwards numerous
on-stained veins penetrate the white shale, colouring a considerable
ortion of it a deep hue.

The present surface of the ground is also covered by a lateritic
eposit which gradually passes into sandstone to the westward,
hile to the eastward at a distance from 10 to 20 chains the granitic
ocks outcrop.

This shale deposit clearly belongs to the Donnybrook Series,
the beds are identical in character with those met with in the
orking beneath the sandstone on the Donnybrook Goldfield.

The deposit is described as a kaolinitic clay shale owing to the
ct that its weathered faces on drying present the characteristic

cleavage, this is lost, however, directly it become wet, when it becomes massive and highly plastic.

The light-coloured portions of this shale, which predominate, dry a dead-white and it has been used locally for white-wash, very similar to china clay, while the red portions become lighter in colour in drying.

EXTENT AND THICKNESS OF THE DEPOSIT.

Owing to the fact that outcrops of this deposit do not occur it is impossible to make any definite statement upon this point, but judging from the fact that it underlies the sandstone series near Donnybrook it is highly probable that it does so in this locality, and should this prove to be the case it will, of course, be met with beneath the sandstone to the westward. To the eastward it cannot extend far owing to the presence of the granite in that direction, while near this outcrop it is highly probable that it has been removed to a considerable depth by the action of an ancient watercourse, evidence of the existence of which is furnished by the detrital matter which is exposed overlying it in the cutting section.

To the northward the surface falls steeply into a fairly deep valley which has been cut through the granite at a distance of some 10 chains from the cutting, while to the southward the surface also falls towards the Capel River at Newlands.

As previously stated, a thickness of 12 feet is exposed in the deepest part of the cutting, while a small bore hole put down at this point proved it to extend for a further depth of six feet, the total thickness of the bed is, however, not proved, since this was not penetrated.

INFERENCE.

The impression created from an extensive study of the surrounding district is that the railway line follows the direction of an ancient valley cut by stream action either at or close to the contact line of the granite with the Donnybrook Series, and at this particular point the deepest portion of this old valley lies on the eastern side of the cutting close to the granite outcrop. In which direction this old river flowed has not yet been determined, but it would appear that at this point the shale deposit was exposed in its bed, or rather upon its western bank in bend of the stream.

Owing to either more recent earth movements or to stream capture, this ancient valley, instead of being occupied by one stream flowing in a definite direction, is now occupied by two, one flowing north into the Violet Brook and one south into the Capel River, while that portion of the valley at which the cutting is situated, and which now forms the water parting of these two streams, has been filled in by the sandy clay and detrital matter exposed in the upper portion of the cutting section.

The red staining of portions of this deposit will probably be nd to extend only so far as the shale bed was at one time ex- ed to atmospheric action, and is directly due to the downward neation of the ferruginous solutions from its lateritic covering, efore in the extension of this bed beneath the sandstone to the tward it will most probably be found to be all white.

The object of the inspection was to ascertain whether this de- it was of sufficient extent to warrant the erection of works for manufacture of roofing tiles, upon which point no definite state- t can be made until it has been further tested by boring, since s clear that only that portion of the bed which is iron-stained be of any value for making red tiles, but judging from the ex- ure in the cutting which averages five feet in height by a length five chains, to which may be added roughly another six feet ved by boring, there is every promise of the existence of ample erial here for all requirements for many years to come.

TABILITY OF THE MATERIAL FOR TILE MAKING.

Mr. Simpson, the Mineralogist and Chemist, in his report pendix I.), speaks in the highest terms of the suitability of the uginous portion of this clay for the manufacture of roofing , though only a very small amount of red clay is suited for tile ing, and the red and white could not be mixed at all for this pose. The writer has seen a very fine sample of terra-cotta e in the form of a water-bottle owned by one of the local resi- ts and manufactured from the red clay, and also a jug of mic ware equal in appearance to the Doulton art ware, which er was manufactured from the white portion of the clay.

Before any definite steps are taken to work this deposit it ld be advisable to put down a few shallow bores with a hand with the object of not only proving the existence of shale of nilar character, but also the thickness of the over-burden, which er will be of material importance in selecting the position most able for opening up a quarry. One or two deeper bore-holes nt also with advantage be put down with the object of ascer- ing the thickness of the bed, while the core would furnish a good of colour of the mixed clays.

CLUSIONS.

1. The red material is admirably suitable for the manufacture high-class, durable, and non-porous roofing tile of excellent ur.

2. That so far as can be judged the deposit is of considerable nt.

3. Its position leaves little to be desired, since a siding can y be constructed into the quarry face; the only drawback will he railway freight, as it is situated at a distance of 141 miles Perth.

st August, 1916.

APPENDIX.

THE CHEMICAL AND PHYSICAL PROPERTIES OF TWO CLAYS FROM NEWLANDS.

(E. S. SIMPSON.)

The two samples of clay from Newlands, in the Donnybrook District, have been examined with the following results. With these are given the results obtained on the sample of Campbellfield (Victoria) white clay, submitted with them.

Physical Characters.—Both local clays were very plastic and extremely fine grained, and, as far as could be seen from the samples submitted, very uniform in character. One clay was greyish white when wet, dead white when dry; the second was of a brownish red colour. The Victorian was very similar to the white clay from Newlands.

Chemical Composition.—The following are the results of analyses made of these clays:—

	2264. White clay.	2265. Red clay.	2408. Campbellfield.
Silica, SiO_2	65.45	61.39	70.99
Alumina, Al_2O_3	21.53	18.12	17.88
Iron peroxide, Fe_2O_3 ..	.94	8.74	1.38
Iron protoxide, FeO	.12	.12	nil
Manganese protoxide, MnO ..	.09	.11	.06
Lime, CaO	nil	trace	.20
Magnesia, MgO	.71	1.00	.94
Soda, Na_2O	.31	.40	.52
Potash, K_2O	1.69	1.98	2.46
Water lost above 100° ..	7.34	6.38	4.64
Water lost below 100° ..	1.96	2.16	1.68
Totals	100.14	100.40	100.75

The analyses were made on thoroughly air-dried samples, and show that there is a considerable difference in the composition of the Victorian and local clays, the latter containing more kaolin and less quartz and felspar than the former.

Firing Tests.—Briquettes were made of each clay separately and of a mixture of 90 per cent. of raw 2264 with 10 per cent. of raw 2265, as it was thought the former by itself might not be sufficiently fusible for the manufacture of stoneware, whilst the latter by itself was expected to be too fusible. Also mixtures of 75 per cent. raw 2264 with 25 per cent. burnt ditto, and of 75 of raw 2264 with 25 per cent. of washed Perth sand. (The latter was not a success.) Specimen briquettes after drying in the air and then by steam were fired at temperatures of 1,050°, 1,250°, and 1,400° (Centigrade), with the following results:—

2264.—NEWLANDS WHITE CLAY.

At 1,050°.—Temperature too low to yield anything but a porous brick.

At 1,250°.—Product a grey vitrified brick with a porosity (water absorption by weight) of 1 per cent. Temperature too low to give good stoneware.

At 1,400°.—Product a light grey well vitrified mass devoid of porosity and of great strength. Burnt at this temperature this clay should yield an excellent drain pipe or other vitrified body, which, judging from the analysis of the raw clay, should take a salt glaze well. The eatest fault of the clay is the large shrinkage it undergoes in drying d burning, viz.:—

	Wet moulded.	Steam dried.	Burnt.
Mean linear dimensions ..	100	91.9	81.2
Mean volumes	100	77.6	53.6

The shrinkage in diameter of a hollow pipe will, of course, be much s than in a solid briquette.

2265.—NEWLANDS RED CLAY.

At 1.050°.—Yields a good hard porous mass of a pleasing terra ta colour and smooth surface, suitable for tiles, flower pots, etc. rosity, 17.1 per cent. Six Marseilles tiles of different brands had osities ranging from 9.3 to 17.5 per cent., the mean being 13.7 per t.

At 1,250°.—Gave a very dark red vitrified mass showing signs at edges of fusion. Porosity. 0.3 per cent. Shrinkage:—

	Wet moulded.	Steam dried.	Burnt.
Mean linear dimensions ..	100	92.1	81.1
Mean volumes	100	78.2	53.3

This clay appears to be unsuited by itself for making stoneware. might, however, be used as a slip glaze for the white clay, or if the ter be not abundant, in admixture with it for the body of the ware.

WLANDS MIXED CLAY (90 per cent. White, 10 per cent. Red).

This gave results similar to those obtained with the white clay. The ulting masses, however, were not as good either in texture or colour those given by the white clay alone, due possibly to imperfect mix- , neither was the shrinkage any less.

NEWLANDS WHITE—MIXED, BURNT, AND RAW.

This gave a well vitrified mass when burnt at 1,400°. Numerous ernal flaws were noted, and were probably due to insufficient grinding the burnt brick, which was only made to pass a 30-mesh sieve. The inkage was reduced to the following figures, viz.:—

	Wet moulded.	Steam dried.	Burnt.
Mean linear dimensions ..	100	92.5	83.6
Mean volumes	100	79.1	58.5

2408.—CAMPBELLFIELD CLAY.

Raw Campbellfield clay burnt at 1,400° gave a mass not quite so l vitrified, and hence neither so impervious nor so strong as the vlands clayware. The shrinkage was, however, much less.

	Wet moulded.	Steam dried.	Burnt.
Mean linear dimensions ..	100	93.1	87.5
Mean volumes	100	80.7	67.0

Conclusions.—There is considerable difference in composition be- en the Victorian and Newlands white clays, resulting in differences behaviour on burning. The Newlands white clay yields a very well ified, non-porous, tough but much shrunken ware; the Victorian clay ds a ware less well vitrified, slightly porous, and less tough, but ving much less shrinkage. The shrinkage of the Newlands white clay be reduced by mixing with a suitable proportion of previously burnt , and should, with careful handling, yield an excellent drain pipe other vitrified ware.

The Newlands red clay is not well suited for making drain pipe or r stoneware, as it might easily be overburnt. It would yield, how- , an excellent roofing tile or other similar ware if burnt at a lower perature (about 1,050° C.).

LIST OF MISCELLANEOUS REPORTS, CHIEFLY ON APPLIED GEOLOGY.

SERIES I.—Nos. 1-8.—Bulletin 26.

(1.) Artesian Water in the Northampton and Geraldine Districts.
(2.) Northward Extension of the Gascoyne Artesian Area.
(3.) Phosphatic Deposits near Dandaraga.
(4.) Meteorite from the Nuleri District.
(5.) Occurrence of Oil in Princess Royal Harbour.
(6.) Greenough River District.
(7.) Recent Advances in the Knowledge of the Geology of Western Australia.
(8.) Prevention of External Corrosion of Goldfields Water Supply Pipes. 1907.

SERIES II.—Nos. 9-32.—Bulletin 48.

(9.) Radium-Uranium Ores from Wodgina.
(10.) Guano Deposits at Watheroo.
(11.) Preliminary Notes on Mineral Resources of Southern Cross.
(12.) Monazite at Cooglegong and Moolyella.
(13.) Country at Heads of Ashburton and Gascoyne Rivers.
(14.) Possibility of obtaining Artesian Water at Moora.
(15.) Kelmscott Clay Deposit.
(16.) Coals from Collie Fields, with Appendix on Spontaneous Combustion of Coal.
(17.) Limestone Deposits at Pinjarra.
(18.) Two new Meteorites from Western Australia.
(19.) Gold Discovery near Goodingnow, Yalgoo Goldfield.
(20.) Peculiar Biotite (Anomite) from Ubini.
(21.) Nemesis Gold Mine, Tuckanarra, Murchison Goldfield.
(22.) Miscellaneous Mineral Notes.
(23.) Boring on Normanby Lease, near Cue-Murchison Goldfield.
(24.) Boring on Duke of York Lease near Cue, Murchison Goldfield.
(25.) Proposed Boring at Nannine, Murchison Goldfield.
(26.) Maori Lass Leases, Southern Cross, Yilgarn Goldfield.
(27.) Diamond Drilling on Violet Lease, Golden Valley, Yilgarn Goldfield.
(28.) Kohinoor South Mines, Stake Well. Murchison Goldfield.
(29.) Diamond Drill Boring on Volunteer Flat, Cue, Murchison Goldfield.
(30.) Geological and Physiographical Notes on the Darling Plateau.
(31.) Rutile at Yulgering.
(32.) Mount Jackson Centre, Yilgarn Goldfield. 1912.

SERIES III.—Nos. 33-51.—Bulletin 59.

(33.) Boring for Coal, Murchison Railway Line.
(34.) Kurnalpi, N.E. Coolgardie Goldfield.
(35.) Rare Metals and their distribution in W.A.
(36.) Ruby Well Centre Peak Hill Goldfield.
(37.) Mikhaburra (Holden's Find), Peak Hill Goldfield.
(38.) Mt. Keith District, East Murchison Goldfield.
(39.) Mt. Magnet, Lennonville, and Boogardie, Murchison Goldfield.
(40.) Yuin, Yalgoo Goldfield.
(41.) Woodline Rush, N.E. Coolgardie Goldfield.
(42.) Kapanga Mine, Greenbushes Tinfield.
(43.) Petrographical Notes on specimens from Greenbushes.
(44.) Golden Ridge G.M., East Coolgardie Goldfield.
(45.) Ilgarere Mineral Leases and Humphry's Copper Find.
(46.) Bremer Range, Country, Dundas Goldfield.
(47.) W.A. Meteorites.
(48.) Kanowna.
(49.) Narra Tarra Mines, Victoria District
(50.) King Sound Tin Mine, West Kimberley.
(51.) Some Rocks from the Phillips River, 1914.

SERIES IV.—Nos. 52-60.—Bulletin 62.

(52.) Coal Resources of Western Australia.
(53.) Mining Geology of Yerilla.
(54.) Certain Mining Centres at the South of the Yalgoo Goldfield.
(55.) Classification of Kalgoorlie Rocks.
(56.) On Concentration Tests of a Tungsten-Molybdenum Ore from Callie Soak, Poona, Murchison Goldfield.
(57.) On Chloritoid and its Congeners with special reference to the Chloritoid at Yampi Sound.
(58.) Geology of Western Australia.
(59.) Mining Fields of Western Australia.
(60.) Geological Observations in the Mulline, Riverina, and Ularring Centres, North Coolgardie Goldfield. 1915.

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By Authority: Fred Wm. Simpson, Government Printer, Perth.

LOGICAL MAPS, REPORTS, AND BULLETINS

ISSUED BY

The Geological Survey of Western Australia.

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**ical Map of Northampton : by A. Gibb Maitland. Scale, 20 chains per inch. Two
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Hayes' New Find ; the Geology of the Bardoc District ; On the Development
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Dominions Royal Commission; British Association for the Advancement of Science; Reputed Occurrence of Oil in Western Australia; Meteorites; Ore Deposits of P.As. 815C and 818C, Leonora; Limestone Deposits of the South-Western Division; The Gold Belt of the Yilgarn Goldfield; Ora Banda; Mount Magnet, Lennonville, and Boogardie; Yuin and the Royal Standard Mine; Darlot Deep Lead; Physiographical Geology of Western Australia; Country between Latitude 23° and 26° South, and Longitude 119° and 121° East; Meekatharra; Sandstone; Mikhaburra (Holden's Find); The North End, Kalgoorlie; Country between Kalgoorlie and Coolgardie; The Bremer Range Country. Price, 1s. 1914.

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Cement-making Materials in W.A.; Possibility of the occurrence of Potash Deposits in the Salt Lake Areas and elsewhere in W.A.; Interstate Conference on Artesian Water Supplies; Reputed Tin Find at Brookton; Geology of the Transcontinental Railway Line; Boring for Water on the Transcontinental Railway Line; Deep Boring at Moora in its Geological Relationships; The Geology and Mineral and allied Resources of the Coastal Plains of the South-West Division; Westonia and Surrounding District; Yerilla; Golden Butterfly Mine, Butterfly, near Kookynie; Niagara; The Country South of Nullagine; Molybdenite at Swan View; Meekatharra and Surrounding Country; Greenbushes; The Country between Kalgoorlie and Mulline; The North End, Kalgoorlie; The Geology of the Mount Jackson and Koolyanobbing Districts. Price, 1s. 1915.

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1917.

WESTERN AUSTRALIA.

GEOLOGICAL SURVEY.

BULLETIN No. 75.

A
Geological Reconnaissance
OF THE
Country between Laverton
AND THE
South Australian Border
(near South Latitude 26°),
Including part of the
Mount Margaret Goldfield,

BY

H. W. B. TALBOT and E. de C. CLARKE,
Field Geologists.

Petrology by R. A. FARQUHARSON.

ISSUED UNDER THE AUTHORITY OF
THE HON. R. T. ROBINSON, K.C., M.L.A., MINISTER FOR MINES.

WITH SIX PLATES AND SIXTY-SIX FIGURES.

PERTH:
BY AUTHORITY: FRED. WM. SIMPSON, GOVERNMENT PRINTER.
1917.

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GEOLOGICAL SURVEY OF WESTERN AUSTRAL

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Do.	E. de C. Clarke
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PREFATORY NOTE.

Two totally distinct classes of geological survey work, necessary to meet public requirements, are carried out by the Department as opportunity offers, viz:—

(a) reconnaissance surveys and explorations, covering in a general way large tracts of country; and

(b) systematic detailed mapping and description of less extensive and individual mining areas.

As has already been pointed out, not the least important class of geological work in such a partially developed country as Western Australia is that represented by the former. Reconnaissance surveys of this kind should theoretically precede the occupation of the country for mining and other utilitarian purposes, and for a good many years to come must in the very nature of things remain the only scientific method possible of dealing with those very large areas of Western Australia which lie beyond the boundaries of connected settlement. Geological surveys of this nature pretend, of course, to nothing more than broad generalised field work of a nature sufficient to furnish a sketch of such of the main geological outlines of the areas explored in so far as they have any bearing upon economic questions, the working out of the strictly scientific problems arising from the field work having of course to be deferred.

Several such reconnaissances have already been made, viz:— King Leopold Plateau (Kimberley Division) in 1901; the country between Wiluna, Hall's Creek and Tanami in 1908-1909; the outlying portions of the North Coolgardie and East Murchison Goldfields in 1911; and parts of the North-West, Central and Eastern Divisions, between Longitudes 119° and 122° East and Latitudes 22° and 28° South, during the field seasons of the years 1912-13-14. To these must now be added that of the country between Laverton and the South Australian border (near South Latitude 26°), the results of the survey of which form the subject-matter of the present publication.

The main purpose of this expedition was the investigation of the mineral-bearing country in the immediate neighbourhood of the Warburton Range, reported by Mr. Frank Hann in 1903. This explorer forwarded samples of the rocks and minerals to the Geological Survey office for examination and assay on his return from the border. The collection, coupled with Mr. Hann's notes, demonstrated quite clearly that in its geological constitution the district resembled in many essential respects that which characterised the goldfields areas of the State. In the more immediate neighbourhood of the Warburton Range the country, according to Mr. Hann's data, was traversed by quartz reefs, samples from which when assayed in the Survey laboratory proved to be demonstrably auriferous.

The matter of an examination of this portion of the State was first contemplated in the year 1905, but it was only in 1916 that the Minister for Mines authorised the despatch of a party for the purpose. After innumerable delays inseparable from the equipping of such an expedition the party, consisting of two field geologists (Mr. H. W. B. Talbot in command, and E. de C. Clarke), four camp assistants, and sixteen camels, left Laverton in June, 1916, provisioned for six months. The main purpose of the expedition was, as set out in the general instructions to the leader, Mr. Talbot, "the investigation of the mineral-bearing country in the more immediate neighbourhood of the Warburton Range reported by Mr. Frank Hann in 1903. To give full effect to this, work should be centered upon (a) the areal distribution, (b) mode of occurrence, (c) the geological relationships, (d) the actual and potential value of the mineral resources of the country, and (e) the study of the structural features of the formation in which the deposits are contained.

The official instructions also set out that "owing to the lateness of the season it is recommended that the most direct route to the Warburton Range should be taken with the object of being able to devote as much as possible of the remaining portion of the winter season in investigations in the district."

Leaving Laverton an east-north-easterly course was followed to a native well on Lilian Creek, on the north side of the Townsend Range, where a depot camp was established from which three flying trips were made, which lasted from the 21st to the 28th of August, from the 30th of August to the 19th of September, and from the 23rd to the 28th of September, respectively.

On the night of the 10th of September the travelling party was attacked by the natives at Mount Gosse, one of the men, J. W. Johnson, being severely wounded, and the leader, Mr. H. W. B. Talbot, receiving some minor injuries from which he rapidly recovered. After returning to the depot camp Johnson failed to make a recovery and it was found necessary to bring him back to Laverton for expert treatment. The whole party, therefore, returned to Laverton, the journey occupying thirty-one days thus curtailing the time available for field work by fully a month.

While very valuable and noteworthy additions were made, not only to the geology, but also the physical geography of the country traversed, the area of possibly auriferous country discovered appears to be small; but there are good grounds for believing it to extend much farther to the north-west and south-west than it was possible for the exploring party to penetrate. Although the samples collected by the party proved to be but slightly gold bearing, the area would deserve further prospecting if not so far removed from all mining facilities that only very rich "shows" could have any hope of being profitably worked. Under any circumstance, before prospecting could be safely or economically carried out it would be necessary to sink at least two reliable wells along the desert route from Laverton to the Townsend Range, and also a good well in the Warburton Ranges, as well as to search for a further extension of the metamorphic basic igneous rocks (greenstones) between the Warburton and the Rawlinson Ranges.

During the journey the combined scientific and utilitarian objects of the department have been steadily kept in view, for so closely are pure science and industrial progress associated that at any moment what might be supposed to be a matter of purely theoretical importance might be discovered to be of highly practical significance and value. In the Wilkinson Ranges, in Latitude South 26° 30′ there was discovered, associated with a series of current bedded sandstones and fine mudstones, an extensive and definite boulder bed about fifteen feet in thickness, of glacial origin. This important discovery is of more than local significance. The precise position in the geological time scale of this interesting and important deposit cannot be definitely fixed, though the somewhat meagre evidence at present available points to the series being of a late Mesozoic or Tertiary age.

A. Gibb Maitland,

GOVERNMENT GEOLOGIST.

Geological Survey Office,
Perth, 22nd January, 1918.

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A GEOLOGICAL RECONNAISSANCE OF THE COUNTRY BETWEEN LAVERTON AND THE SOUTH AUSTRALIAN BORDER (near SOUTH LAT. 26°), INCLUDING PART OF THE MOUNT MARGARET GOLDFIELD.

CHAPTER I.

GENERAL INFORMATION.

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I.—CHARACTER AND RESULTS OF EXPEDITION.

No other remote portion of this State has been visited by so many explorers as that just north and south of the 26th parallel of latitude and between longitude 126° and the South Australian border (see Frontispiece). From this region have, from time to time, been brought specimens of rocks resembling those associated with the auriferous formations of the goldfields. The impression has thus been created that this country is mineral-bearing, and therefore deserves geological examination.*

As far back as 1905 such an examination was contemplated by the Government, but for various reasons it was decided to postpone the work and it was not until May, 1916, that instructions were issued by the Hon. the Minister for Mines that an expedition to examine and report on the country in question was to be undertaken as early as possible. With this end in view a party consisting of two Field Geologists and four camp assistants with 16 camels, provisions for six months, and the necessary equipment, left Laverton on 29th June, 1916. A general east-north-easterly course was followed to a native well on Lilian Creek on the north side of Townsend Range. Here a depot was established, from which flying trips with riding camels were made through the country to the northwards and eastwards.

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* This subject is discussed on pp. 146 and 147.

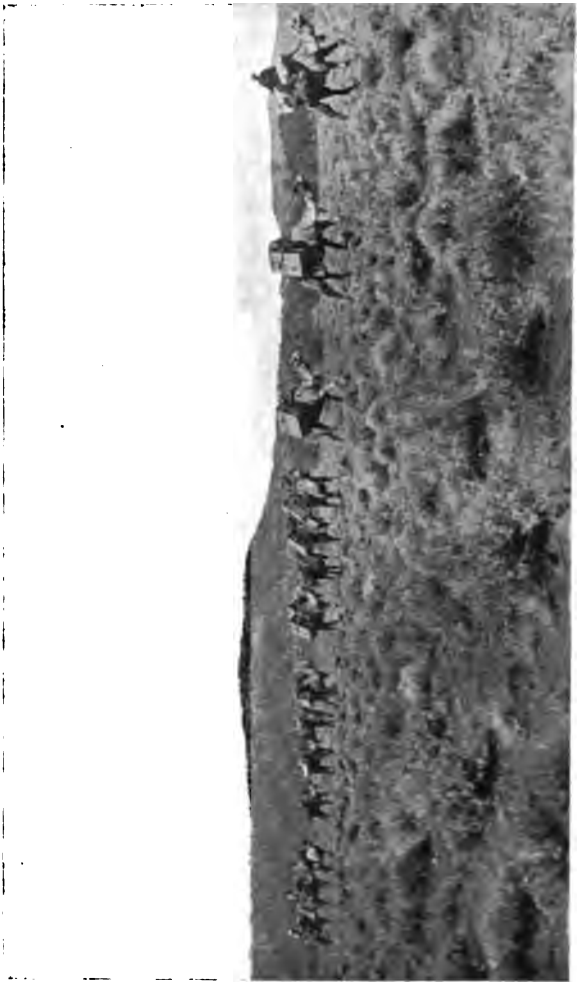

Fig. 1.

Photo: H. W. B. Talbot. Neg. 1513.

PARTY ON RETURN JOURNEY, NEAR BLACKFELLOW POINT.—

In background are Breakaways in Wilkinson Range Series.

The party was attacked by blacks at Mt. Gosse, one of the men being severely wounded and the leader receiving minor injuries. It was found necessary to bring the wounded man back to Laverton for proper medical treatment, and the time available for field-work was thus curtailed by fully a month.

For information of future travellers it may be noted that, during our journey, blacks were very scarce between Laverton and the Townsend Range. Between Townsend Range and the South Australian border they were fairly numerous but very wild. Probably there is amongst them a certain number of "outlaws" from civilized parts. It will be necessary for parties to keep watch at night if they suspect that blacks are in the vicinity.

The expedition was fortunately made towards the close of a good season, so that little difficulty was experienced in finding sufficient water at all stages. But for our enforced early return, a larger area of country would have been mapped, and a much more accurate conception of its geology gained.

From the time the party left Laverton until it reached Mt. Gosse no points accurately located by survey were touched, although most of the hills had been visited by explorers and their positions indicated on the map with as great a degree of accuracy as can be expected in exploratory work of this character.

On leaving Laverton, a compass traverse was begun, distances being estimated by the time taken in travelling between various points, and frequent observations were made to determine the latitude. When the traverse from Laverton to the trigonometrical survey station at Mt. Gosse was calculated, it was found that it closed correctly as regards latitude, and that the easting had been over-estimated by 170 chains. In a traverse of over 500 miles, this is less than a half of one per cent. The error was apportioned over the traverse, and the route as shown on the maps attached to this report is probably as accurate as a compass reconnaissance can be.

In the vicinity of the Cavenagh, Blackstone, and Morgan Ranges the rocks were so highly magnetic that they materially affected our compasses; and in other localities occupied by acid rocks, such as Mt. Squires, Warburton Cairn, and Lightning Rock, compass bearings were unreliable although the local attraction was not nearly so great (less than 3°) as in proximity to the gabbros and dolerites.

Readings, usually with three aneroids and two thermometers, together with meteorological notes, were taken at nearly every camp, and, during September and October, at 9 a.m. and 3 p.m. (mean State time). The readings were used for the calculation of the heights recorded on the map as follows:—

They were corrected for index error (and diurnal variation if necessary) and the mean reading for the two or three aneroids was taken as the reading for the spot. The barometric reading for the same time at Laverton (and occasionally in the eastern part of the trip, at Charlotte Waters also) corrected for temperature was further corrected if necessary by inspection of the isobars on the Commonwealth Weather Chart for the day. The required height was then obtained by the formula quoted on p. 87 of the "Text

Book of Topographical Surveying" by Major C. F. Close, issued by the War Office. The heights are entered on the map to the nearest multiple of 10 feet.

With the exception of a few stations, the heights of which have not been placed on the map, discrepancies between the two sets of observations taken between Laverton and Townsend Range on the outward and inward journeys did not exceed 50 feet. In spite, therefore, of the fact that heights determined by us between Barrow and Cavenagh Ranges exceed those of the Elder Expedition by two or three hundred feet, we regard ours as more nearly correct.

Mr. E. B. Curlewis of the Commonwealth Meteorological Bureau has, by the standardisation of our instruments, by supply of required data, and by helpful suggestions contributed largely to the success of this part of our work.

Owing to the nature of the traverse, the great extent of the area mapped, and the limited time at the disposal of the party, no detailed geological mapping was undertaken. Practically every rock outcrop passed was examined and noted, and from the information thus gained and the general topography, the boundaries of the various geological formations were drawn. One hundred and thirty-four of the rock specimens collected were brought back to Perth (see Appendix B). Most of these have been examined and determined by Mr. R. A. Farquharson, Petrologist to the Department (see Appendix A).

The net result of the expedition has been the discovery of a small area of probably auriferous country (pp. 116-118), of a fair extent of pastoral land (pp. 118-121), and of a number of facts of considerable scientific interest.

The scientific results of the expedition are discussed in the next two chapters and in the appendices; the economic possibilities of the region, being inferences from the scientific results, are summarised in Chapter IV.

We are much indebted to Mr. F. R. Feldtmann, Field Geologist, for his reading and criticism of Chapters I. to IV. while they were in MS. form.

II.—DESCRIPTION OF COUNTRY.

The country, from the point at which the traverse commenced to the Townsend Range, is typical of the "desert" areas of the interior of the State. The monotony of sandy flats and sand-ridges is relieved occasionally by low breakaway-cliffs. None of these are much more than a hundred feet high, and few more than fifty feet, but so flat is the country that, from the top of one breakaway, another cliff that may be thirty miles away shows up quite conspicuously. In the sandy country "spinifex" is the predominant growth, although on some of the sandy flats there are occasional clumps of mulga and thick scrub. "Desert" and "mallee" gums are usually associated with the "spinifex," and in places there are some "wattles," quondongs, and other bushes which afford fair feed for camels.

At the base of the breakaways, and extending out from them for distances varying up to a mile, there are usually loamy flats on which grow mulga, salt-bush, and, after rains, grass and herbage of various kinds. On these fringing belts the traveller can usually find a fair camp for camels or horses. In the vicinity of the breakaways, too, are found water-holes and soaks that afford the only surface water of the region.

Farther east, between the Townsend Range and the South Australian border, the country is of quite a different type to that just described. Rounded hills and broken ranges take the place of the low breakaways, and the flats between them are often formed of rich soil which in a good season supports a fairly luxuriant growth of grass and flowers of different kinds in addition to the permanent scrub.

The type of country just described is not more than thirty miles wide, but has a much greater range from east to west. To the north and south a monotonous expanse of sand-ridges with occasional low breakaways extends to the horizon.

III.—OUTLINE OF GEOLOGY.

The country described in this report is most conveniently considered, from a geological point of view, in three sections:—

> *The Warburton Area,* in which sedimentary, igneous and metamorphic rocks—some like those of Kalgoorlie, etc.—are developed, and which includes all the country between Townsend Range and the South Australian border;
>
> *The Dunge's Hill—Townsend Range Section,* in which the only "rocks" other than superficial deposits, so far discovered, are horizontal sediments of no economic value;
>
> *The Laverton-Dunge's Hill Section,* in which rocks common in the West Australian goldfields are found.

The main geological features of the country examined by us may be simply described as follows*:—

"Greenstones" (*i.e.*, greenish-black doleritic rocks much altered —"metamorphosed"—by earth movement and frequently, but mistakenly, spoken of as "diorite") usually very fine-grained, occupy a small part of the Warburton Area and of the Laverton-Dunge's Hill Section. They have a general resemblance to some of the greenstones common in Western Australian mining centres. The greenstones are broken through ("intruded") by—

Porphyry Dykes and Granite.—The porphyry, which is very prominent in the Warburton Area, where it forms three very large dykes, is a hard, dark, flinty rock through which are scattered small crystals or rounded blebs, about the size of currants, of quartz or pinkish felspar. The granite varies a great deal in coarseness, in the amount to which it has been sheared by earth-movements, and in colour, but forms one continuous mass with (where it borders on the greenstones) a finer-grained edge composed of a porphyry which has not the crystals and blebs of the dyke-porphyry previously mentioned, and which looks rather like quartzite. The porphyry dykes, as well as this porphyry-edging, though very different from the granite in appearance, are simply finer-grained phases of it.

---

* Proofs of the statements in this section are submitted in Chapter III.

In the Laverton-Dunge's Hill Section the granites are like those of the Western Australian goldfields; hardly any porphyry was noticed.

There is also an entirely distinct group of *sedimentary rocks*, the majority of which, being composed of fragments of older rock, are termed agglomerates, greywackes, etc. The rocks of this group have, like the greenstones, granites, and porphyries, been altered by earth-movements and occur in small patches in the Warburton Area. This group, which is of no economic importance, is the youngest of the Archæan or Pre-Cambrian rocks. Strata somewhat similar in general appearance are found at Kurrawang, etc., near Kalgoorlie.

Breaking through (or "intruding") all the rocks so far mentioned are long, wall-like dykes, and also great irregular masses (or "batholiths") of rocks which, in contrast to the greenstones, may be called "blackstones." The *blackstones* are coarse in grain, black in colour, and jointed but not sheared like the greenstones. They thus frequently form steep faces which look like rough masonry (see fig. 29). Rocks (gabbros, norites, and dolerites) exactly like these in microscopic structure have been found in various parts of Western Australia; and some of the finer-grained types have been found to cut across lodes and reefs at Sandstone and other centres.

Practically nothing is known as to the age of the blackstones, but in the Warburton Area they are probably as old as the next group of rocks which has been called—

The Townsend Range Series, because the white or yellow quartzite, of which Townsend Range is composed, forms such a large part of it. Volcanic rocks, conglomerates, impure limestones (not to be confused with "travertine," often called limestone, which is purely a surface-deposit occurring on top of rocks of any age) and grits lie underneath the quartzites in the Townsend Range Series, but it is difficult without technical detail, given in the third chapter and in Appendix A, to distinguish any but the quartzite from some of the older rocks already described. In order, however, that prospectors may know whether they are on true greenstone-country (where they may find reef-gold) or on the lower beds of the Townsend Range Series (where they will find none) it should be sufficient for them to note the geological colours and their own position on the map (Plate II.).

The geological age of the Townsend Range Series is thought to be Ordovician.

A great interval of time elapsed between the laying down of the rocks of the Townsend Range Series and that of the next group, which occupies all the Dunge's Hill-Townsend Range Section, and is called the *Wilkinson Range Series.* It consists of horizontally bedded sandstones, claystones, and boulder-beds, probably of rather late (Mesozoic or even Tertiary) age. Though of no known economic importance, this series is of considerable scientific interest because there is evidence that, while it was being laid down in the shallow sea which then covered these parts, glaciers flowed down to the sea from the north, *i.e.*, from the tropics.

Chapter III. contains a brief summary of the work of other geologists in and near the country traversed by us, and detailed accounts of the various formations referred to above. Persons desiring information only on the economic possibilities of the region will find what is known on this subject in Chapter IV. Those requiring further particulars on geological matters will find in Appendix A. detailed petrological descriptions of rock-specimens, arranged in the same order as the detailed geology of chapter III. The pages (either in Appendix A. or elsewhere) on which there is mention or description of any petrological specimen will be most easily found from Appendix B, in which the registered numbers of specimens are arranged in numerical order.

IV.—PLANT AND ANIMAL LIFE.

Had it been possible, throughout the trip, for one man to devote his time to botanical and zoological notes and collections, some interesting additions to the fauna and flora of Central Australia would probably have been made, more particularly as an exceptionally good season was in full swing over the region we traversed. The best we could do was to make a fairly complete dried collection with notes as to habitat, etc., according to a scheme drawn up by Dr. F. Stoward of the Agricultural Department, of plants found in flower on the outward journey to Townsend Range, and to preserve, in formalin, specimens of the phyllopods, etc., inhabiting most of the water holes. The botanical specimens and notes have been handed to Dr. Stoward, who has very kindly undertaken to examine and report on them. The phyllopods, etc., have been given to Professor W. J. Dakin of the University of W.A.

It is regrettable that we could not attempt to collect the many varieties of insects (especially butterflies), lizards, and birds which, under the exceptional conditions, were very abundant, or to secure specimens of the smaller marsupials which no doubt occur in these parts.

A specimen of the ordinary brown snake (*Demansia nuchalis*), a new species of lizard of the genus *Physignathus*, a jerboa rat (probably *Notomys Mitchelli*), and tadpoles (*Lymnodynastes ornatus*) were presented to the Perth Museum and have been identified by Mr. L. Glauert.

We were struck by the almost complete absence of larger animals from the tract between Townsend Range and Laverton. In this distance of nearly 400 miles the only marsupials seen were "spinifex rats," two or three rock wallabies and one kangaroo. One dingo (others were heard at nights), a large domestic cat, and several rabbits complete the list of land animals other than snakes, lizards and birds which we observed in this part. That it has supported kangaroos is witnessed by the remains of brush "fences," probably twenty years old, used by the blacks in their hunting drives, and by bleached bones on old camping grounds. Possibly kangaroos make periodical incursions in different directions, only visiting the same tract at long intervals.

In the Warburton Area, with its larger extent of pastoral country, there would appear to be a settled population of kangaroos, rabbits, etc., which, judging from their shyness, are pretty constantly harried by the blacks.

Regarding plant-life, two facts of a general nature arrested our attention: firstly, as we travelled east, the character of the flora appeared to change so that near Laverton and the South Australian border respectively, different plant-associations are found occupying country similar in soil, aspect, etc.; secondly, it was frequently found that a plant-species formed a notable feature in a small patch of country and then, though soil, aspect, etc., seemed unchanged, disappeared, to reappear in another patch perhaps many miles away.

V.—PREVIOUS EXPEDITIONS.

The first explorer to visit the country described in this report was Mr. W. C. Gosse,* Deputy Surveyor General of South Australia, who, in 1873, set out from Alice Springs in South Australia to make the overland journey to Perth. He penetrated into this State as far as the western end of the Townsend Range, but then had to turn back owing to want of water.

In 1873-74 Mr. Ernest Giles† spent several months in the country between the Warburton Range and the South Australian border. With three companions and twenty-four horses he left Ross's Waterhole on the Alberga River in South Australia on 4th August, 1873, with the object of travelling overland to the settled districts of Western Australia. He crossed the Border on 30th

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* Gosse, W. C.—" Reports and Diary of Mr. W. C. Gosse's Expedition in 1873." S.A. Parl. Pap. No. 48, 1874.

† Giles, E.—" Australia Twice Traversed."—London, 1899. Two Vols.

September, and from that time until the end of the following June made numerous attempts to find a route to the westward, but he was unable to cross the desert that lies west of the 126th degree of longitude. Twice at points about 100 miles apart he penetrated as far as longitude 125½°, each time nearly losing his life, and, finally, after undergoing great hardships and losing one member of his party, Gibson, he was forced to retreat to South Australia.

In March, 1874, Mr. (now the Right Hon. Sir John) Forrest,[*] with his brother Mr. Alex. Forrest as second in command, two white men, and two aboriginals, commenced his successful journey to the overland telegraph line in South Australia. He reached the north-western edge of the country under review early in August, and, following an east-south-east course, crossed the Border on 22nd August, reaching his objective on the telegraph line on 27th September. The party had pack horses to carry the provisions, and at times suffered from scarcity of water.

In 1891 a party commanded by Mr. David Lindsay[†] was fitted out by Sir Thomas Elder. It left Warrina in South Australia on 2nd May. The Border was crossed near Mt. Agnes, and the country in the vicinity of the Cavenagh and Barrow Ranges was visited. From Mt. Squires, Lindsay turned south-westward to Queen Victoria Spring. Mr. Victor Streich was attached to the party as geologist. Streich's geological work is referred to in Chapter III.

In 1894 the Hon. D. W. Carnegie[‡] and "one Luck," on a traverse northwards from Queen Victoria Spring to Mt. Shenton, crossed our route nearly at right angles in the vicinity of Point Salvation.

On November, 1895, a party under the command of Mr. S. G. Hübbe [§] left Oodnadatta in South Australia with the object of reporting on the possibility of opening a stock route from the settled districts of South Australia to the Eastern Goldfields of this State. They crossed the Border near Mt. Hinckley on 9th April, 1896, and followed approximately Forrest's route of 1874 to Alexander Spring, from which point they steered a general south-westerly course to the mining township of Niagara.

In 1897 Mr. Hugh Russel[||] led a private prospecting expedition from Mt. Margaret to Mt. Squires. At the latter place he established a depot, and spent about two months prospecting in the Barrow and Cavenagh Ranges without, however, finding any auriferous country. Leaving Mt. Squires, a traverse was made to the Warburton Range, and from that place the party turned southwards and hit their outward tracks, which they followed back to civilisation.

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[*] Forrest, J.—"Explorations in Australia."—London, 1875.
[†] "Journal of the Elder Scientific Exploring Expedition" Adelaide, 1893.
[‡] Carnegie, Hon. D. W.—"Spinifex and Sand" London.
[§] Hübbe, S. G.—"Stock Route Expedition from South to West Australia." S.A. Parl. Pap. No. 51, 1897.
[||] "West Australian Year Book," 1902-4, p. 89.

In 1901 Mr. R. T. Maurice,* in command of a South Australian party, crossed the Border a little north of latitude 28°. Steering north-north-west to the Jameson Range, he then turned north-north-east to the Rawlinson Range, from which point he travelled south-south-east and again entered South Australia near Mt. Gosse.

Mr. Frank Hann has made several journeys from Laverton to the South Australian border, and it was along his route that we travelled as far as Lilian Creek. Hann has visited nearly every hill in this region, and we found very few waters that were missed by him. His usual equipment consisted of riding horses and a few camels to carry water and provisions. He was always accompanied by a Queensland native named Talbot, who had been with him for many years, and some white man who was anxious to see the country usually joined his expeditions.† Hann has done exceedingly useful work in this district, and his mapping of the physical features compares favourably with that done in other parts of the State by more elaborately equipped explorers.

VI.—PRINCIPAL WATERS ON THE ROUTE.

The country between Laverton and Townsend Range is almost devoid of conspicuous landmarks, and it would be difficult to find many of the waters without some particulars as to their whereabouts; so, for the benefit of future travellers in this region, it has been thought advisable to give bearings and distances between the different waters, with other directions that may assist in finding them.

None of the waters except the well at Lilian Creek can be regarded as permanent, and the great majority of them are gnamma-holes or rock-holes, which depend entirely for their supply upon the rain which falls in the immediate neighbourhood. At times some years elapse without any general rains, and the waters are replenished only by thunderstorms. These storms are notoriously erratic in the way they travel; one locality may receive a downfall of inches, while perhaps less than half a mile away only a few drops fall. Therefore, unless one is assured that the country has been visited by general rain, finding one rock-hole full is no guarantee that the next will contain any water.

Some of the rock-holes of large size will not hold water as long as some of the smaller ones. This may be due to leakage through joints or bedding-planes, but more often to lack of shelter from the sun's rays.

To one who has travelled in the desert region between Wiluna and Hall's Creek, the entire absence of native wells on the flats between the sand-ridges is remarkable. At intervals along the Canning Stock Route native wells and soaks are found, many containing permanent supplies of water; but in the country between Laverton and Lilian Creek, where the country has a similar geological structure, the only waters seen occur on the top, or at the base, of breakaways.

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* Maurice, R. T.—Extracts from Journals, S.A. Parl. Pap. No. 43, 1904.

† A short account of one of Mr. Hann's journeys was given in *The Kalgoorlie Miner*, July 21, 1906, and of another in *The West Australian*, March 1, 1907; see also "West Australian Year Book," 1902-4. pp. 93-4.

Between Lilian Creek and the South Australian border, the configuration of the country is entirely different from that to the westward. Broken ranges and conspicuous hills take the place of the low breakaways, and the hills shown on the map can be easily identified. Directions for finding the waters in this region are, however, given, as many of them occur in unexpected places, and would be difficult to locate from a small-scale plan.

The distances given in the following notes are in a direct line from point to point, and generally a greater distance than indicated would have to be actually travelled owing to the difficulty in steering a perfectly straight course over a country devoid of land-marks, and to detours to avoid sand-hills, breakaways, or thick clumps of scrub.

The bearings given have been corrected for local variation. The two prismatic compasses used differed in their readings by two degrees, so it is considered advisable to give true bearings.

A well-defined bush road leads from Laverton in an easterly direction, and in about eight or nine miles hits an old tram line from Beria. The road and the tram line then run close together to McCalmont's windmill, situated sixteen miles from Laverton. It was from this windmill that our traverse started. From here a few sulky and horse tracks lead past Point Kidman, Manning Gnamma-Hole, and the Ivor Rocks to Pine Tree Caves, a distance of about twenty-one miles. Some pastoral country has been taken up to the northwards of Pine Tree Caves, so that the track thence to the windmill will probably become more distinct.

To the south-east of Point Kidman, where the track crosses a small creek, surface water will be found for a short time after rain.

At two and three-quarter miles from Point Kidman, the Manning Gnamma-Hole is reached. This hole lies about thirty chains east of the end of the line of breakaways which extend from Point Kidman. There is an excellent camel camp (salt-bush and mulga) to the east. When full it holds about 300 gallons.

From the rocks near the gnamma-hole, Ivor Rocks are seen bearing 62°, and beyond these the Bailey Breakaways, in which the Pine Tree Caves are situated, show up conspicuously. At the caves there is a water-hole at the base of the cliff which would last for some time after rain, and is easy of access to horses or camels (although the latter are frightened of the caves and rocks). On the top of the cliff are several rock-holes, one of which will hold water for some months after being filled. Horses could be taken up a narrow path about 150 yards west of the bottom water. If the cliffs are followed about 20 chains south-east there is a passage to the top by which camels would be easily taken to the large rock-hole. At the Pine Tree Caves there is an excellent camel camp even in times of drought, there being an abundance of salt-bush and some good mulga.

Fig. 2.

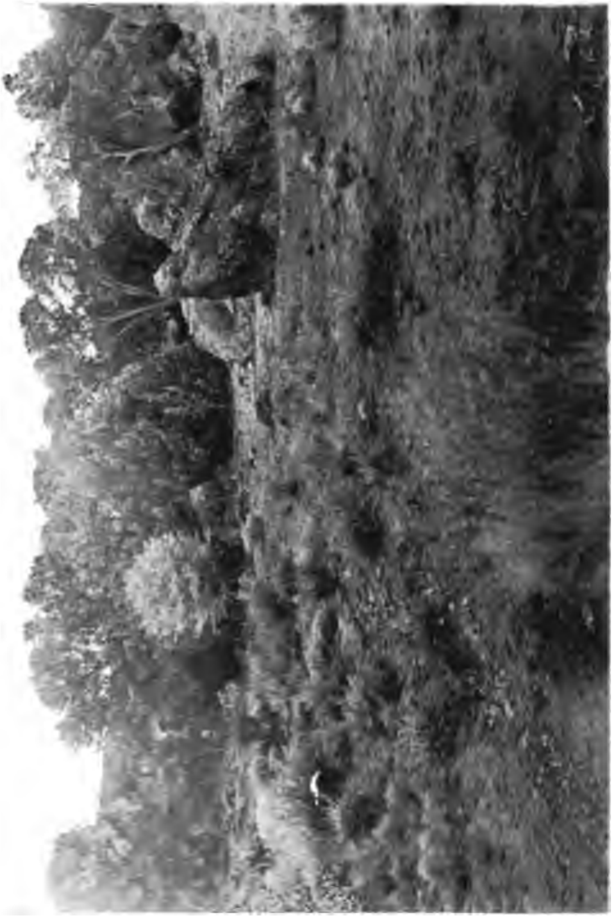


Photo: E. de C. Clarke. Neg. 1108.

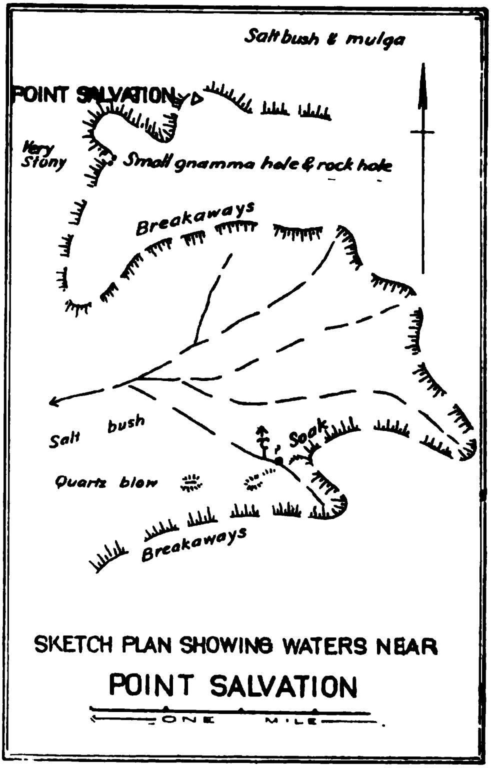
"PINE TREE CAVES." Undercut Granite Breakaways.

After leaving Pine Tree Caves the next water we saw was at Point Uhr. On our outward journey we travelled *via* Mt. Sefton and Point Freeman, but on our return we took a direct route, thereby saving several miles. In a creek that runs north-east from Mt. Sefton, water would probably be found in a good season, but if there were water here, the rock-hole and soaks near Point Uhr could be relied upon; so as there is less stony ground by the direct route, it is recommended to travellers. When going from the caves, the Bailey Breakaways should be ascended at the place mentioned above about 20 chains to the south-east, and then an east-north-east course will lead over sandy spinifex flats and through thick clumps of mulga for about fourteen miles. The northern end of a line of breakaways extending south-east to Point Freeman is then reached and some conspicuous breakaways are also seen to the northwards. From here Point Uhr is visible about nine miles to the north-east. It may be easily recognised by its double-humped appearance. The first four miles after leaving the extension of the Point Freeman breakaways, is occupied by red soil and very thick mulga, but then an open sandy flat is entered, which extends to within half-a-mile of Point Uhr. From the top of Point Uhr some piled-up granite rocks are seen about half-a-mile to the north-east. In a watercourse near the base of the rocks there is a soak, which, although quite dry at the time of our visit would be a good watering place after heavy rain. There are numerous cork trees near the soak, and on some of these visitors have cut their initials. If the creek is followed down for about a mile it is seen to spread out on a red soil flat, and on this flat there is another soak, which although dry when we saw it, would hold water for a long time after the watercourse had flooded the flat. At the head of this creek, where it rises in the breakaways, about 60 chains west of the first soak referred to, there is a large rock-hole holding about 1,000 gallons with several smaller holes above it. On our outward journey all the holes were full, but on our return, about four and a half months later, the large hole was dry, although there was some water in one of the smaller holes above.

From Point Uhr, Point Salvation shows up on a bearing of 78°, the distance being twenty-two miles. The first two and a half miles leads through fairly thick mulga, followed by seven miles of spinifex and mallee, with sandy soil under foot. Then a belt of travertine, about four miles wide, on which grow mulga, quondongs, and other bushes, and on which are some good camel camps, is crossed. Stock water would probably be obtained here at a shallow depth. After crossing the travertine, sandy soil, with spinifex and mallee, extends to within three miles of Point Salvation, when the spinifex is left and mulga becomes the principal growth. At the head of a gully on top of the cliffs facing west near Point Salvation, there are two small holes. One is a gnamma-hole holding about 50 gallons. Its opening is very narrow and evaporation would be slight. Though too small to be of use for stock, it would serve to replenish water cans. Water in the other hole, which is a small cave with a shelving bottom, would not last nearly as long as in the gnamma-hole. Numerous game-pads lead along the top of the breakaways to the holes.

About a mile south of these holes is a good soak which, if cleaned out, would probably yield a large supply. It could be easily found by travelling southwards along the breakaways from Point Salvation for about 60 chains; the cliffs then turn to the east, and a creek with numerous branches flows westwards. From any rising ground a white quartz blow can be seen a short distance to the south-east with more breakaways behind it. From the quartz blow the soak bears a little north of east and is distant twenty-five chains. It is situated in a creek below a bar over which the creek flows.

Fig. 3.



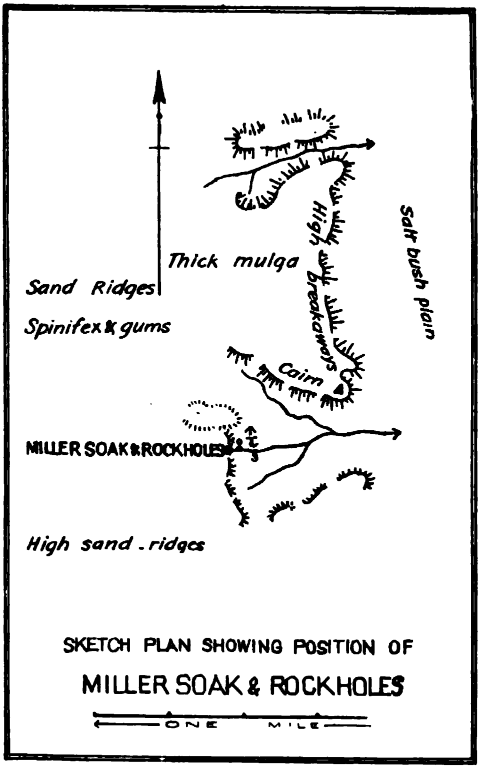
SKETCH PLAN SHOWING WATERS NEAR POINT SALVATION

From the cliffs at Point Salvation, Dunge's Table Hill can be plainly seen bearing 80° and distant eleven miles. For four miles some very stony ground is traversed, when Reetz Creek is reached. This we followed down for about five miles, and then left it and travelled over two miles of spinifex and mallee to Dunge's Table Hill. There are a few holes along the creek which would hold water, but in all probability a month's hot weather would dry any of them up. Water would probably be found at a comparatively shallow depth at the lower end of Reetz Creek. From the summit of Dunge's Hill we could see that this creek spreads out over mulga flats to the north-east.

From Dunge's Table Hill we followed a general course of 75° to Point Sunday. A short distance to the eastward of the table hill there is a stony salt bush flat followed by a belt of mulga about three-quarters of a mile wide. Sandy spinifex country with occasional sand-ridges is then encountered, and this class of country extends to Point Sunday. This point is first seen from the top of a sandy rise about six and a-half miles away at the same time that Mallee Hen Point, bearing 87° and distant about three and a-half miles, becomes visible. On the top of Point Sunday there is a large gnamma-hole holding about 400 gallons. On our outward journey the hole contained about 300 gallons, but the natives had put mulga branches in it, and the water smelt horribly and was unfit for use. Several of the gnamma-holes which we saw afterwards had mulga packed in them. Presumably the natives have stronger stomachs than white men or even camels, and do not mind the stench or taste which the mulga gives the water. In all probability the mulga is put in to lessen evaporation, but this method could be easily improved upon by laying some sticks across the hole and covering them up with branches. We cleaned the hole out and on our return found about a hundred gallons of water, due to a thunder storm a few days earlier.

The next water is at Miller Soak and Rock-holes which lie about thirteen miles E.S.E. by E. from Point Sunday. The easiest way to find the soak is to go eastwards for seven miles, when thick mulga will be met. This mulga grows along the top of rough breakaways, where the travelling is difficult. Instead of entering the mulga, the traveller should keep to the edge of the spinifex leaving the mulga on his left. In about five or six miles the end of a sand-ridge running south-westwards is reached. To the eastwards of this point a valley running through some breakaways is seen. This may be followed down, and when the eastern face of the breakaways is reached they may be followed southwards for about 60 chains to a bluff on which we built a cairn. From the cairn the soak is half a mile distant on a bearing of 240°. Instead of following the valley mentioned above, a shorter route is found by turning southwards round the end of the sand ridge, still keeping the mulga on the left. In about a mile this will lead to a flat between two cliffs, from which the cairn we built can be seen, and the soak which is amongst some rocks near the head of a creek can be picked up from the bearing given above. There is a very good camp for camels or horses east of the soak, but the water cannot be relied upon in a dry season. The rock-holes do not last very long, the soak would require a lot of work before any supply could be obtained, and it is doubtful how long the soakage would last.

Fig. 4.



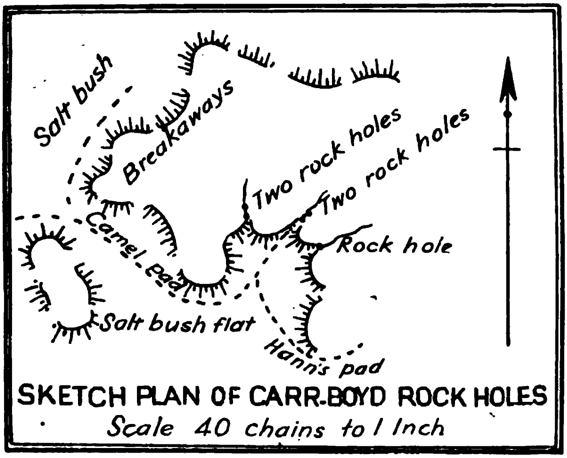
From Miller Soak some breakaways are seen about nine miles to the east, where there are five large rock-holes named Carr Boyd Rock-holes by Hann. They can be easily found with the aid of the sketch plan below.

After the holes are filled, they will hold water for many months, and there is a splendid camp for horses or camels along the foot of the breakaways.

The next water that we saw was the Lily Rock-hole in the Wilkinson "Range," about twenty-one miles north-east of the Carr Boyd Rock-holes in a straight line. However, in order to avoid getting bogged in Lake Yeo or the marshy flats that run out from it, it is necessary to travel a little to the north of east for about fourteen miles, and then to steer northwards to the south end of the Wilkinson "Range," which is visible from any rising ground or a high mulga. Close to the south-eastern end of the Wilkinson "Range" there are two flat topped hills. From the most northerly of these the gorge in which the Lily Rock-hole is situated can be seen on a bearing of 27 degrees and distant about two and three-quarter miles. The Lily Rock-hole will contain water for several months after rain, and there is another hole below and two above that will hold water for a shorter period. There is a good salt-bush flat about a mile to the south-west of the rock-holes.

The next water that would last any time is at Amy Rocks, about thirty-five miles E.N.E. by E. of Lily Rock-hole. In the intervening country we noted only two outcrops, Sunday Surprise Rocks, fifteen miles from Lily Rock-hole, and Winterbottom Rocks (fig. 24) twelve miles further on. At both places there are small gnamma-holes, but the water in them would not last long, and they are hard to find as they are visible only for a short distance to the south. From Winterbottom Rocks, Mt. Brown can be seen about twenty miles away bearing 101°, but nothing else is visible but large sand-hills. It is difficult to give directions for finding Amy Rocks owing to the absence of landmarks, but from a high point about sixty chains south of the rock-hole, Winterbottom Rocks bear 253°, and are distant about eight miles. From the high ground east of the hole, Millar Breakaways can be seen to the E.S.E.

Fig. 5.

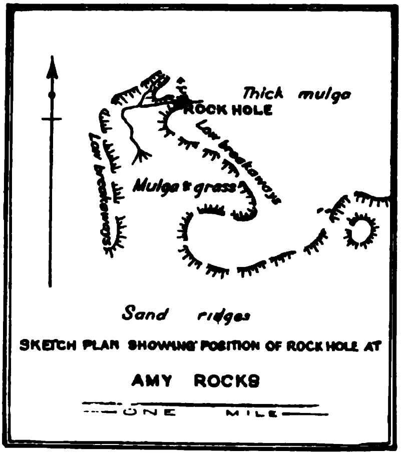


SKETCH PLAN OF CARR-BOYD ROCK HOLES

Scale 40 chains to 1 Inch

At the south-eastern end of Millar Breakaways there is another good rock-hole at the base of a low cliff near the head of a flat trending N.N.E. between breakaways. From the top of a bluff on the S.E. side of the range, a large clay-pan is seen about a mile to the east, and from this bluff the rock-hole bears 200° and is distant half a mile. The clay-pan mentioned was dry when we saw it. There is a splendid camp for camels or horses at Millar Breakaways, where there is abundance of salt-bush and, after rain, of herbage.

Fig. 6.



From the south-east end of Millar Breakaways a conspicuous bluff can be seen bearing 80° at a distance of eleven and a-half miles. This is Point Saunders near which there are some fairly good rock-holes. If the traveller goes north-east from the Point Saunders bluff along the face of the cliffs for about 60 chains, he will see a gully coming out of the breakaways, and, near the head of this gully among the rocks will find a large rock-hole (fig. 19). When we first saw this hole on 2nd August, it was full of water. We called here again on 18th October, and no rain appeared to have fallen in the interval. The hole was much lower, but we were able to water fifteen thirsty camels and fill our cans without exhausting the supply. There is another hole about 200 yards to the west which is more accessible to camels, but being open and shallow does not last long.

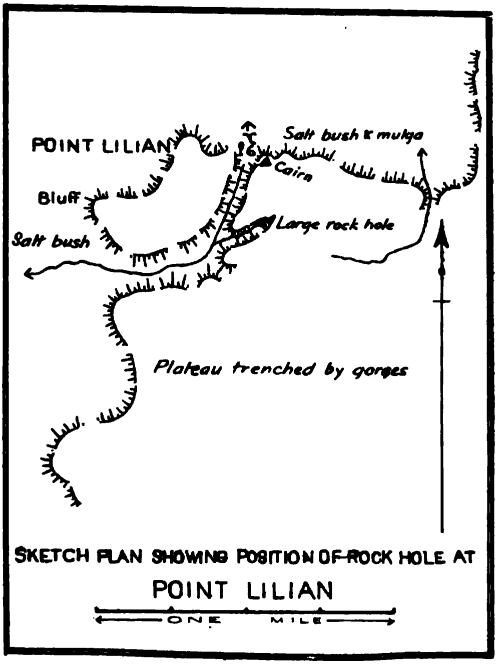
About five miles E.N.E. by E. from Point Saunders and visible from it, there is a low bluff facing south. Our course took us over a ridge extending northwards from the bluff. From a sand-ridge two miles further on, on the same course, we sighted some breakaways bearing 68°, and, travelling along the edge of the spinifex (to the right) and the mulga (to the left), reached them in six miles. Several sandstone outcrops were seen on our left, and some of these had small gnamma-holes among them.

From the breakaways last mentioned a large clump of gums is seen about a mile and a half to the eastward. Here a large creek loses itself in the sand, and in the bed of the creek above the gums there is a sand-soak, which was, however, dry when we saw it.

From the breakaways a long line of low cliffs can be seen about 20 miles to the north-east, in which is Point Lilian bearing 56°. The country between these points is nearly all occupied by sand-ridges.

At Point Lilian there is a large rock-hole in a deep gorge. The sketch plan will show how it can be found. We built a cairn on the top of the breakaways, and a game-pad runs past this to the rock-hole. To get horses or camels to the water it is necessary to go eastward from the cairn along the base of the breakaways for about half a mile, when the creek shown on the plan is seen running northwards. Animals can be taken up this creek to the

Fig. 7.



top of the breakaways and thence close to the rock-hole, from which water must be hauled in buckets. It was not possible for us to judge how long this water would last, as both times we saw it the hole had been filled by rain a few days previously.

From Point Lilian, Point Irwin can be seen bearing 30° and distant about eight miles; and, two and a half miles on from Point Irwin, another line of breakaways, facing north-west, commences and runs north-north-east past Point Reetz. A little south-east of Point Reetz there is a gnamma-hole on the top of the cliff. The cliffs here run in a fairly straight line, and it is difficult to give directions for finding the water. It is about seven miles from Point Irwin, which may be easily identified, and is in latitude 27° 29′ 1″ by observation. From Point Reetz, Fetherstonhaugh Hill and Faulkner Hill are visible above the sand-ridges in the far distance to the north.

Cooper Hills are about twelve miles from Point Reetz on a bearing of 35°. At three-quarters of a mile from the most westerly hill, on a bearing of 20°, there is a large gnamma-hole on a bare patch of laterite on flat ground. It is on a badly defined water channel; there are some sand-ridges a little to the west, and open mulga with many old native camps around the hole.

Cooper Creek lies about a mile and a half north-east of the gnamma-hole, but where we crossed it there was no water, although the creek had run a few days previously. Mr. Frank Hann tells us that there is never much water in this creek, but about four miles above where we crossed it water is to be found for some time after rain.

On the top of Ryan's Bluff, which lies about nine miles north-north-east of Cooper Hills, there is a peculiar gnamma-hole, circular in shape, about three feet six inches in diameter, and about five feet deep. When we saw it it appeared to be nearly empty, but there is a cave running eastwards from the bottom of the hole. We poked a stick eight feet into the cave and then may not have reached the end of it. It is impossible to state how much water could be got here, but in all probability the hole would yield a fair amount. Though difficult of access, some route for animals up the breakaways could probably be found.

From Ryan's Bluff, Hann Table-Top (Fig. 15) shows up conspicuously four and a half miles away on a bearing of 343°.

The Hann line of breakaways commences at Point Wood, about two and a half miles north-north-east of Ryan's Bluff, and extends north-north-west to Fetherstonhaugh Hill, at which point it swings round to the north-north-east and runs, with a few small breaks, as far as Manton Knob. In all probability there are numerous gnamma- and rock-holes in these breakaways. We saw several which are shown on the map, and all of them, except perhaps the Henning Rock-hole, could easily be found with the aid of the plan.

Henning Rock-Hole is in a small rocky creek running west from the breakaways, which lie about a mile and a half to the east. About twenty chains below the rock-hole this creek joins a gum creek flowing southwards. For some distance from the rock-hole in all directions there are the remains of many blacks' fires, showing that the water here must last a long time. The hole is quite small on the top, but there appears to be an underground cavern extending under the sandstone. On our return journey the hole was full of sand but we got all the water we required by digging out a little sand, when there was a great rush of water from behind.

About a mile on from Fetherstonhaugh Hill there are clay-holes in a creek which hold water for a few weeks after rain.

At Watt Creek there are some very large water-holes, some of which would last for at least a year. It would be reasonable to expect to find water here at almost any time; at any rate if all the holes in Watt Creek were dry there would be little likelihood of the traveller reaching this point.

In the creeks south-west of Manton Knob there are some good rock-holes, from the best of which Manton Knob is distant three-quarters of a mile on a bearing of 57°.

From Manton Knob the top of Point Read just appears above the sand-ridges on a bearing of 36°, and a little over nine miles distant. On top of the breakaways eight chains south-south-east of Point Read there is a good gnamma-hole. As the hole has a small opening it is protected from the sun and should last some time. When found it was packed with mulga, but this was removed, and on the return journey the hole was full and the water quite good.

Simpson Hill and also the Warburton Range can just be seen above the sand ridges from Point Read. The former bears 23° and is distant seven miles. After rain there is a little soakage water in a creek about half a mile east from Simpson Hill.

Fig Tree Gnamma-hole, which holds about 150 gallons, is situated on top of some low breakaways, which have a semi-circular shape and face north-west. It is distant three and a-half miles from Simpson Hill on a bearing of 32°. From the high ground near the gnamma-hole, Weekly Hill can be seen almost due west at a distance of five miles and the western end of the Warburton Range bears 5°.

There is a small gnamma-hole, holding about 100 gallons, nine miles on from Fig Tree Gnamma-hole on a bearing of 64°. It lies amongst some low broken hills, and, unless our tracks were followed, would be difficult to find. From it a conspicuous hill at the west end of Townsend Range bears 62°.

From the above locality, there are two routes to the native well on Lilian Creek which there is no difficulty in finding. The best way is to go round the west end of Townsend Range and then steer for the very conspicuous bluff about six miles to the east. The well is on the creek less than half-a-mile from the bluff. The other route is along the southern side of Townsend Range to the wide gorge which Lilian Creek has cut through the range. The creek may then be followed up to the well. The well yields a large supply of good stock water, which is rather hard for washing and too "sweet" for good tea. We had a depot camp here for about two months and nobody was affected in any way by drinking the water.

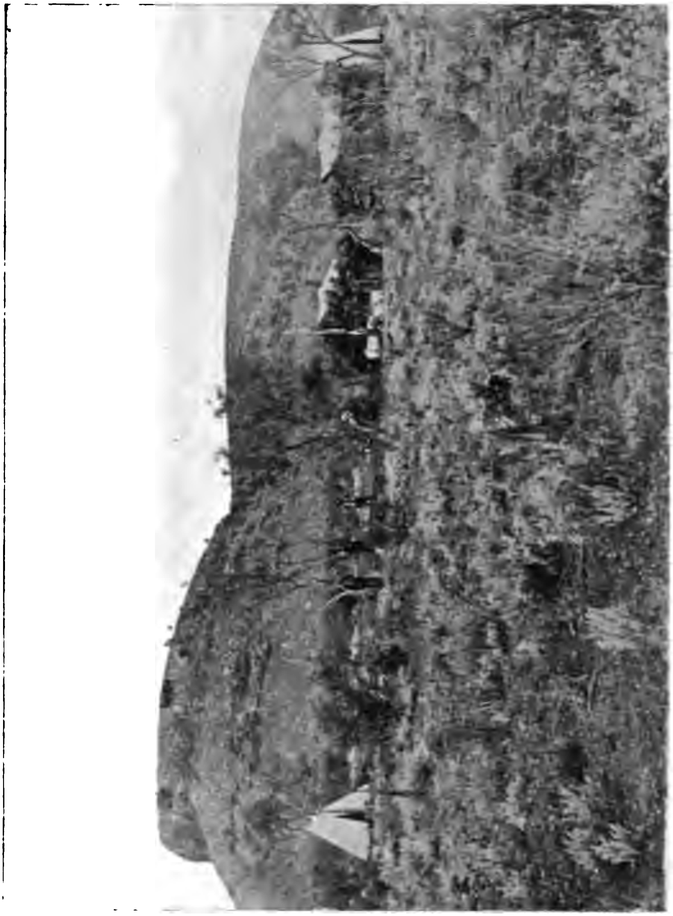


Fig. 8.

Photo: E. de C. Clarke. **DEPOT CAMP. Townsend Range.** Neg. 1475.

We saw no water in the immediate vicinity of the Warburton Range. Some very large creeks which rise in the range unite and ultimately run out on a flood plain a few miles below the junction of the Hughes and Elder Creeks. At the time of our visit these creeks had not apparently run for some time; we saw several native soaks which were quite dry. Some of these soaks would probably contain water for some time after the creeks had run, but Giles, who was in this locality in 1873, apparently in a good season, states that any water he saw in the creeks was too bitter for drinking.

The nearest water of any consequence to the Warburton Range known to us is at "Spring Granite," found by Sir John Forrest in 1874, about two miles east of the head of Scamp Creek, and about four miles from Scamp Hill, which lies on a bearing of 204°. At "Spring Granite" there is a large water-hole on the east

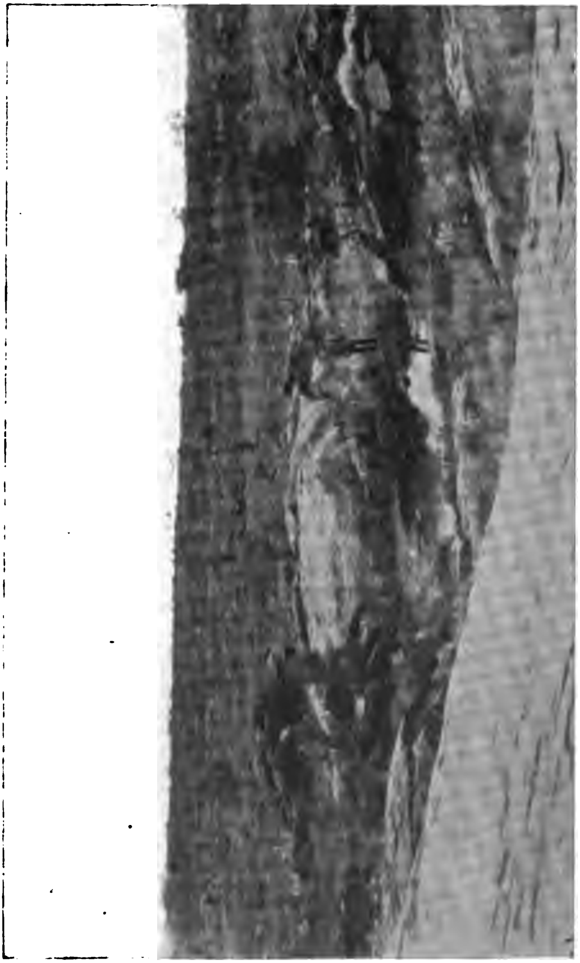


Fig. 9.

Photo: H. W. B. Talbot. Neg. 1506.

"SPRING GRANITE."—Discovered by Forrest in 1874.

side of a large bare granite outcrop. The hole would hold water for a long time, and it is more than likely that there would also be a soakage in the bottom. There is a good catchment and light rain would put water in the hole. There is some good pastoral country around the rocks.

About six miles south of "Spring Granite" we saw two small gnamma-holes in granite. From the rocks above the holes Scamp Hill bears 297°, Warburton Cairn 214°, Miller Hill 180°, and Mt. Herbert 143°.

Two and a-quarter miles from these gnamma-holes, on a bearing of 64°, there is a conspicuous mass of red granite, on the west side of which there is a cup-shaped gnamma-hole which when full would hold about 300 gallons of water.

On the west side of Mt. Eveline, there is a fine water-hole on the north side of a rough and deep gully which rises near the top of the mount. It is about twenty chains above where the watercourse runs out of the gully on to the flat. This waterhole might almost be called a spring, as water can be seen trickling into the hole from the rocks above. Water would probably be obtained here at any time unless the country was suffering from a severe drought. If blacks were about this would be a dangerous place to approach. as spears could be thrown by natives hidden amongst rocks on the steep slopes of the gully.

On the south side of Mt. Squires there is reported to be a water called Giles Tank, discovered by Giles in 1874, and visited by Russel in 1897. We did not see this water, but we saw a fairly large, almost inaccessible, rock-hole, not shown on the map, in the range about a mile south of the cairn.

In a deep rocky gully, about a mile E.S.E. from the cairn on Mt. Squires, we saw running water flowing into several holes. Other holes were nearly dry, and in all probability unless rain fell the flow of water would cease within a month or two. This water is of little value as, owing to the rough nature of the country, it would be impossible to get stock near it.

About four miles east of Mt. Squires are three rocky granite hills. On the top of the most southerly of these, there are numerous pine trees and on the east side of this, there is a soak (Lamb Soak). At the time of our visit this had fallen in, but by digging some of the sand out, we saw that water could be obtained if required.

One hundred chains from the above soak on a bearing of 285° there is a larger and better soak on the north side of a rough, rocky hill. The soak is on a natural platform not far above the base of the hill, and there are numerous blacks' camps on the flat below it. This water would probably last a long time.

About thirteen miles N.N.E. of Mt. Squires there is a good rock-hole in a cleft in some bare granite rocks. The water is well sheltered from the sun's rays and should last a long time. This water was first found by Sir John Forrest in 1874 and has since been visited by several explorers. Hann has cut several names in large letters on the rocks. Mt. Burt lies three miles to the N.W. and Minnie Hill eight miles to the east.

Thirty-five chains from Lightning Rock on a bearing of 164° there is a large rock-hole at the base of a bare granite outcrop.

Fig. 10.

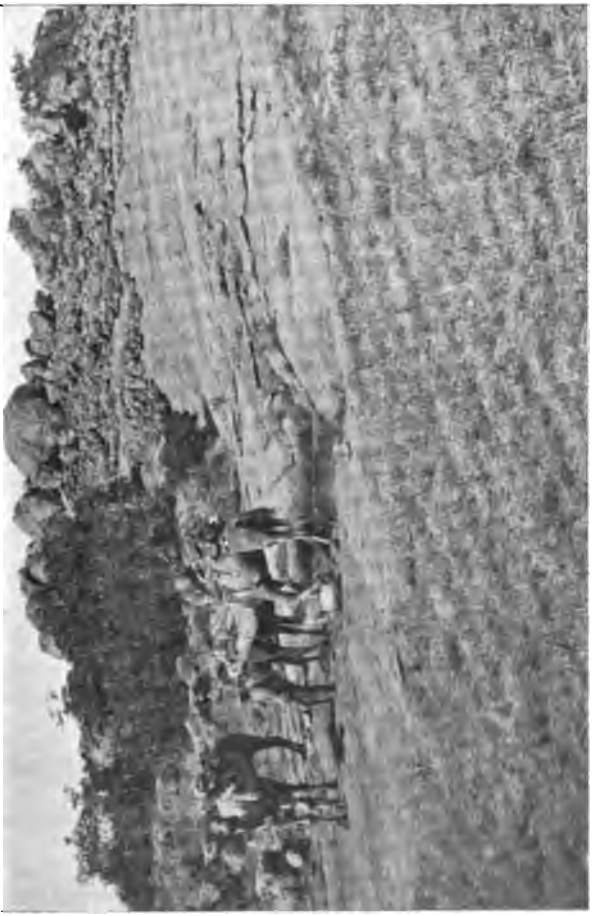


Photo: E. de C. Clarke. Neg. 1480.

ROCK-HOLE NEAR LIGHTNING ROCK.—Discovered by Giles in 1873.

Owing to the open nature of the hole evaporation would be rapid, but there appears to be a considerable depth of sand in the hole, and when the water got below the level of the sand evaporation would be much slower, and a supply of water would probably be preserved in the sand for a long time after rain had fallen.

Forrest and Giles in their journals mention a fine running spring at Fort Mueller.* At the time of our visit the watercourse was quite dry and probably runs only after a very wet season.

About five miles W.N.W. from Fort Mueller there is a spring found by Hann in a very dry season, and called Fort Welcome by him. The spring is situated in a rocky gorge at the head of a valley running in an easterly direction into the range. The visible supply of water is small but it would probably be replenished as it was drawn upon. Care would have to be taken when watering stock at Fort Welcome as the natives could easily spear one from the rocks above the spring.

On the north side of Barnard Rocks, which lie seventeen miles east-north-east from Fort Mueller, there is a rock-hole and soak where water could be obtained for a few months after rain. From the rocks, Mt. Aloysius bears 75°, and a round hill, with a tree on top, is distant 140 chains on a bearing of 263°.

When steering in a direct line from Barnard Rocks to Mt. Aloysius, three rocky hills are passed when within eight miles of the mount. At the north end of the middle hill there is a small soak. Not requiring water at the time we did not clean out this soak, but it appeared to hold very little water, and did not give promise of yielding a good supply by sinking.

In a deep gully, which heads near the top of Mt. Aloysius, runs south-west for about a mile and a-half, and then swings round to the south, we found a series of pools with running water between some of them. If not permanent, this water would last a long time, but it is quite inaccessible for camels. A route by which horses could be taken to the water might be found, but it would not be possible to take them up the creek the way we walked.

Near Amy Giles Rocks there is a good rock-hole and soak, distant 20 chains on a bearing of 26°. From the rocks, Mt. Aloysius bears 148°, Mt. Hinckley 118°, and Mt. Gosse 78°.

A few more small waters were seen, but they were derived from recent rains and in a dry season the knowledge of their whereabouts would be of no value to travellers.

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* The "Blackstones" of Cavenagh Range often weather into forms resembling ruined castles—hence, presumably, the word "Fort."

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I.—INTRODUCTION.

The portion of the State dealt with in this report lies on the great plateau of Western Australia, which in this part has an average elevation of between 1,500 and 2,000 feet above sea-level. Jutson[*] is inclined to regard this plateau as a vast, uplifted peneplain.

Between Laverton and the South Australian border two distinct types of country were traversed, which are described below as the Desert[†] and Hilly Zones. The Desert Zone is distinguished by almost complete absence of notable hills and the frequency of breakaway-country. In the Hilly Zone many hills and ranges rise above the general level of the peneplain.

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[*] G.S.W.A. Bull., No. 61, p. 20.

[†] Arid conditions of course obtain in both zones.

II.—DESERT ZONE.

This zone extends along our route from Hammer Hill to Townsend Range. As already noted it is characterised by general uniformity of level and absence of hills.

The lowest point determined by us was on Lake Yeo (1,230 feet above sea-level), which is 300 feet below Laverton (130 miles distant in a straight line), and 670 feet below Axe Hill (about 210 miles away, and the highest point between Laverton and Townsend Range).

The following table shows the heights, determined by aneroid, of various places along our route across the desert:—

Locality.	Altitude.	Distance from preceding locality.
	feet	miles
Laverton *	1,530	
Point Uhr	1,560	40
Point Salvation	1,650	22
Dunge's Table Hill	1,570	10
Point Sunday	1,530	15
Miller Soak	1,490	13
Carr Boyd Rock-Holes	1,470	10
Lake Yeo	1,230	10
Lily Rock-Hole	1,380	12
Near Camp 19	1,450	7
Amy Rocks	1,320	25
Millar Range	1,430	7
Point Saunders	1,530	13
Camp 26	1,390	13
Camp 27	1,360	12½
Point Lilian	1,530	7
Point Roetz	1,530	14
Camp near Cooper Creek	1,490	12
Base of Faulkner Hill	1,630	15½
Top of Faulkner Hill	1,760	
Camp No. 33, 2½ miles N.W. of Fetherstonhaugh Hill	1,570	7½
Point Craig	1,690	8
Manton Creek	1,760	12½
Point Read	1,730	10
Simpson Hill	1,820	7
Fig Tree Gnamma-Hole	1,800	3
Axe Hill	1,900	13
Depot Camp	1,660	10

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* Starting point of Expedition.

A.—Sand-Country.

1. **Sand-Plains.**—Between Hammer Hill and Point Salvation there are extensive sand-plains covered with the ubiquitous spinifex. Gnarled and twisted desert gums are dotted about on these "spinifex"

plains and give them when viewed from a distance the appearance of open park-land. Here and there on these plains are thick clumps of mulga, and occasionally a little wattle and quondong.

The sand-plains overlie granite, and, in the area occupied by sedimentary rocks to the eastward, their place is taken by sand-ridges. On the sand-plains there are occasional sand-ridges, but they are so few and far between that they can be easily avoided by the traveller.

It is difficult to account for the fact that, while the sand derived from granite tends to spread out over a comparatively level surface, in the sedimentary area, and to a lesser extent over the area of acid rocks near the South Australian border, it is piled in long ridges. It may be that the sand yielded by the western granite is coarser than that derived from the weathering of the other rocks mentioned, and that it is too heavy to allow the wind to arrange it in the form of ridges. There is, no doubt, a good deal of movement in the sand on the granite area, but it appears to lead to levelling-up rather than to dune-building.

The sparse covering of "spinifex" materially retards moving of sand by wind. On our outward journey we crossed patches that had been recently burnt by natives, and on our return our previous tracks were almost obliterated, while on the unburnt area they were quite distinct. These remarks regarding the retardation of sand movement by the growth of spinifex apply also to the sand-ridge area to be presently described.

There is no great amount of evidence as to the depth of the sand deposits on these plains, but in all probability it is inconsiderable. In the middle of one of the plains a small outcrop of granite was noticed; and, in a similar sand-plain on the stock route that extends from Wiluna to Kimberley, bores that were put down, showed that bedrock was nowhere more than fifty feet below the surface.

2. **Sand-Ridges.**—One of the most remarkable characteristics of the interior of Western Australia is the enormous development of sand-ridges which extend from the northern edge of the Great Southern Plain northwards to Kimberley, and eastwards to the South Australian border, from a line drawn from near Condon on the North-West Coast through Erlistoun, and thence southwards. The continuity of the sand-ridge area is broken occasionally by salt lakes and ranges of hills, but the largest known break is that which will be dealt with in this report under the heading of Hilly Zone.

North of latitude 26° the general trend of the sand-ridges, except in proximity to the ranges and hills, is east-south-east and west-north-west; but in the area under review the ridges have no particular direction, although for considerable distances they are parallel to one another. In the northern latitudes the prevailing wind is from the south-east, and one of us, who has spent some years in the areas further north, has known these winds to blow in the daytime with sufficient velocity for three weeks without a break to fill the air with dust and fine sand. There can be no doubt that the uniform direction of the sand-ridges in the north is due to their formation parallel to the direction of the wind, and that their deviation from their usual trend in proximity to hills is accounted for by the change in direction of the wind near elevated and broken ground.

That the sand-ridges in the country traversed by the expedition do not conform to the almost universal trend of those further north may be ascribed to greater variableness in the direction of the wind. No information was obtainable regarding the direction of the prevailing wind in this region, but a record was kept by us from July to October. This is shown in diagrammatic form in Fig. 11. An

Fig. 11.

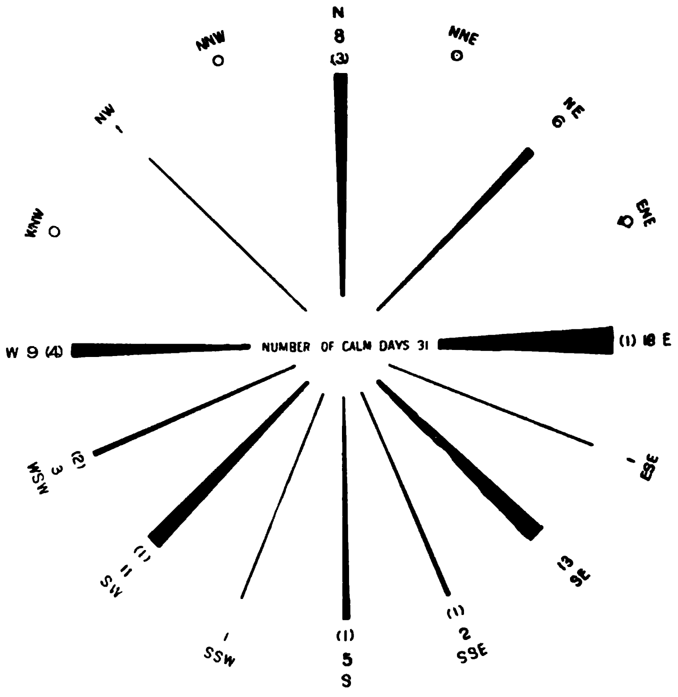

Diagram. Showing direction & frequency of wind from July to October 1916.

1 . Wind from this quarter for 1 day (Relative frequency indicated by thickness of wedge)

(1). Strong wind from this quarter for one day inspection of this shows that, except from the north-west quadrant with only one windy day, winds blow from all directions. It appears that we were too far south to feel the effects of the steady south-east trade winds which blow in lower latitudes.

The distance between the sand-ridges varies from about two hundred yards up to nearly a mile, and the average height is about thirty feet.

The vegetation of the sand-ridge areas is very similar to that which grows on the sand-plains previously described, but there is a larger variety of plants. "Spinifex" is, of course, the predominant growth. Desert gums or mallee are usually seen, but while the former grow on both the ridges and the flats between them, mallee is never seen above the base of the ridges. Mulga, too, does not grow on the ridges, although in some localities there are dense clumps of it on the flats. Parakylia grows luxuriantly and in places disputes pride of place with the spinifex.

3. **Lakes and Clay-Pans.**—Occasionally, in the sand-country, both of the Desert and of the Hilly Zone, small clay-lined depressions, perhaps a few acres in extent, were found in which water lies for some days after rain. The largest of these "clay-pans"* was that, seen but not visited, near Millar Range. Some distance west of our route lies "Baker Lake." On the outward journey this feature was clearly marked from the Hann Breakaways by the clouds of dust driven eastward off the bare ground by the strong wind.

The country between Blackfellow Point and Wilkinson Range is, according to Mr. Hann, mainly occupied by "lake country" belonging to Lake Yeo. As is well known, "lake country" in Western Australia presents no scenic attractions, nor, usually, even water, and is particularly exasperating and even dangerous to a party equipped with camels. Fortunately for our progress, only a few of the small eastern arms of Lake Yeo were encountered.

B.—BREAKAWAY-COUNTRY.

1. **General Remarks.**—Frequently, in various parts of the State, an explorer has seen in the distance, and named as a range, some line of higher country which a later traveller in the same region has been unable to locate.

The elusiveness of many West Australian "Ranges" is usually attributable, not so much to faulty mapping, as to the fact that these "ranges" are of the peculiar "Breakaway" type, which, though rising boldly above the general level on some sides, on others passes imperceptibly into sand-country.

Except Mt. Sefton and a few granite knolls like those near Point Uhr, breakaways are the only type of elevation seen at close quarters along our route from Laverton to Townsend Range.

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* **An account, by Tate & Watt, of clay-pans and their probable origin will be found in Rep. Horn Exped., Part iii., pp. 22–23.**

Though the following remarks are broadly applicable to breakaways in granite-country, regarding which a good deal has been written,* we propose to deal more particularly with breakaways

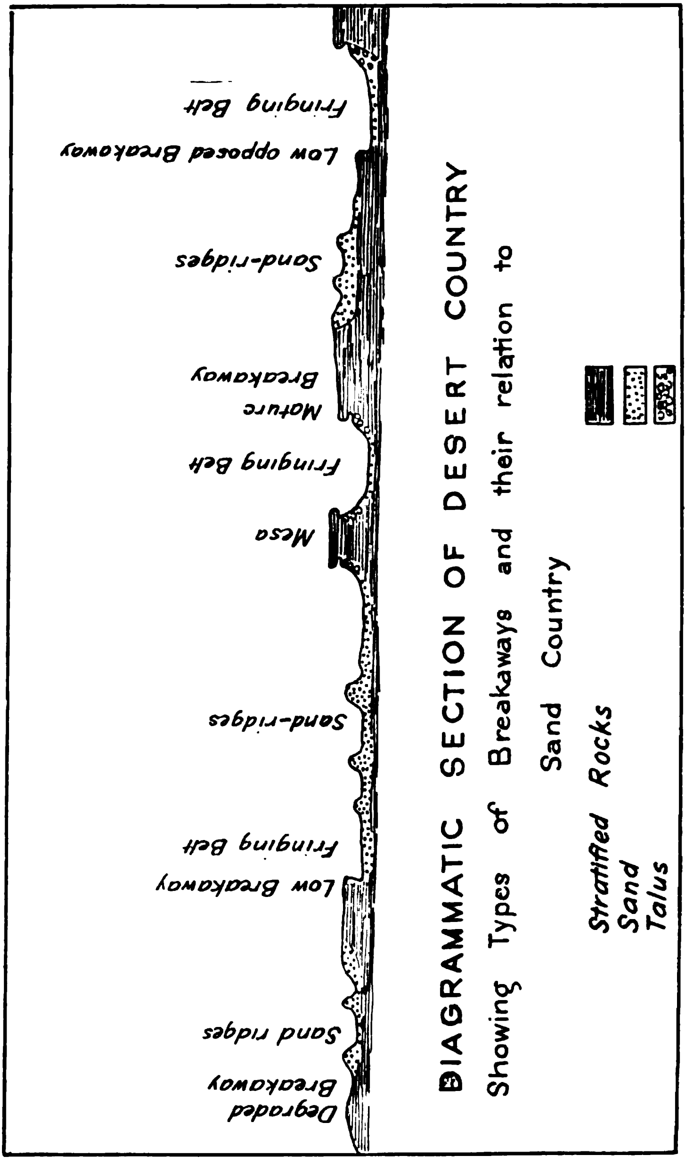

Fig. 12.

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* For example G.S.W.A. Bull., No. 45, pp. 36-7 (Talbot), No. 57, p. 20, *et seq.* (Woodward), and No. 61, p. 144, etc. (Jutson).

formed in the horizontal sediments which occupy the country between Dunge's Hill and Townsend Range.

By the terms "Breakaways" and "Breakaway-Country," we refer to the many patches of more or less "solid rock" which, from some points of view at any rate, rise steeply above the sand country already described to heights varying from a few feet to a maximum of 150 feet. The terms include both isolated "Table-Tops" (buttes or mesas), like Sunday Hill, Dunge's Hill, etc. (Fig. 15), and lines of cliff-bordered country like Hann and Bailey Breakaways or Wilkinson Range (Figs. 16, 17).

Fig. 13.

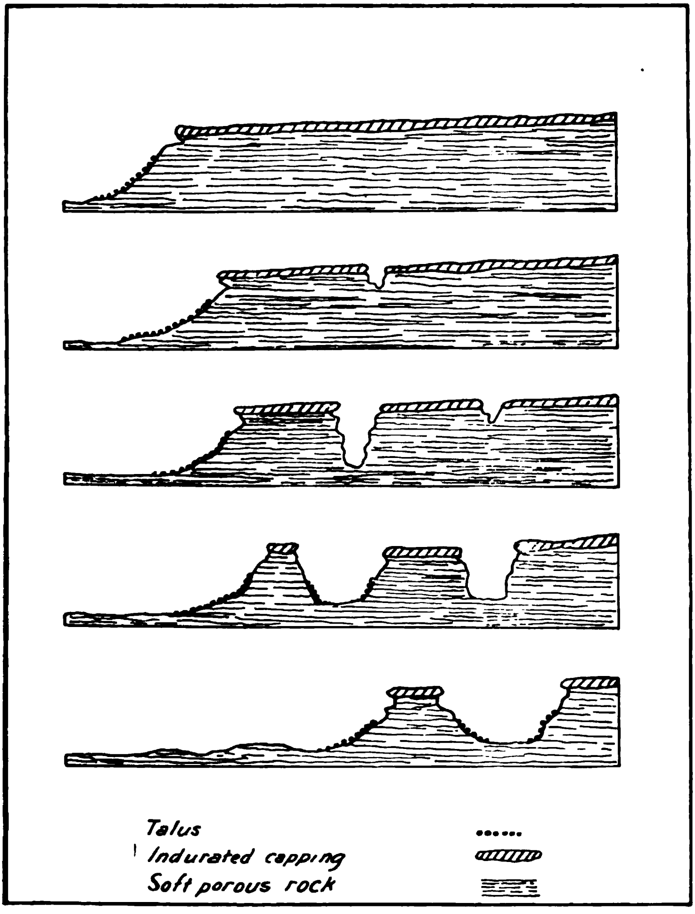

Diagram showing the progressive weathering of a breakaway.

Invariably, breakaway-country is an approximately flat-topped rocky tract bounded on one or more sides by steep or vertical faces; but, while the island-like "Table-Tops" are surrounded by cliffs, and are thus typical buttes or mesas, the larger patches of breakaway, though rising abruptly above sand country on some sides, in some directions merge gradually into it. This peculiarity, together with the uniform level of the country between Laverton and Townsend Range (see p. 40), shows that the general configuration must be somewhat that represented diagrammatically in Fig. 12.

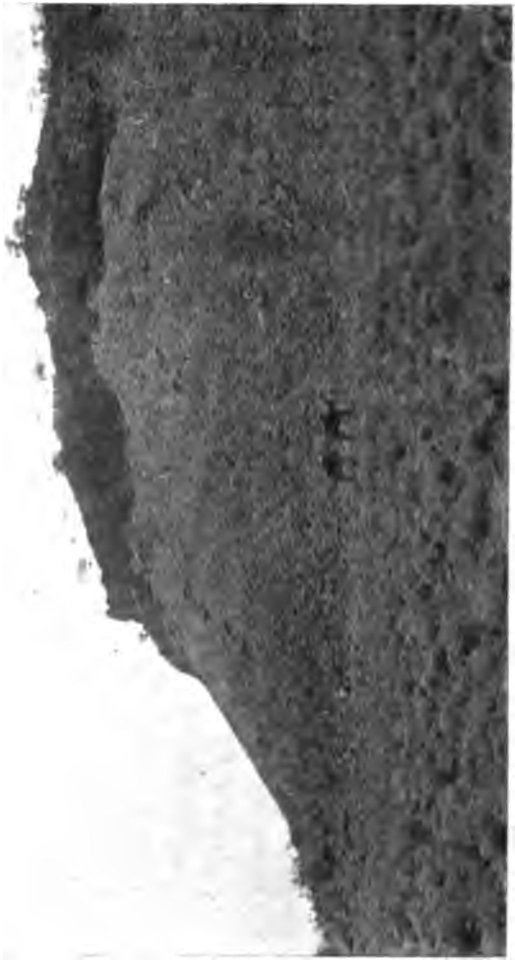

Fig 14.

Photo: H. W. B. Talbot. Neg. 1512.

BLACKFELLOW POINT.—A mature Breakaway.

On examination of the map of our route it will be seen that the breakaway cliffs may face in any direction, although the long, west-facing line between Point Lilian and Manton Knob gives, on first inspection, an idea that this western aspect is the favourite.

Fig. 15.

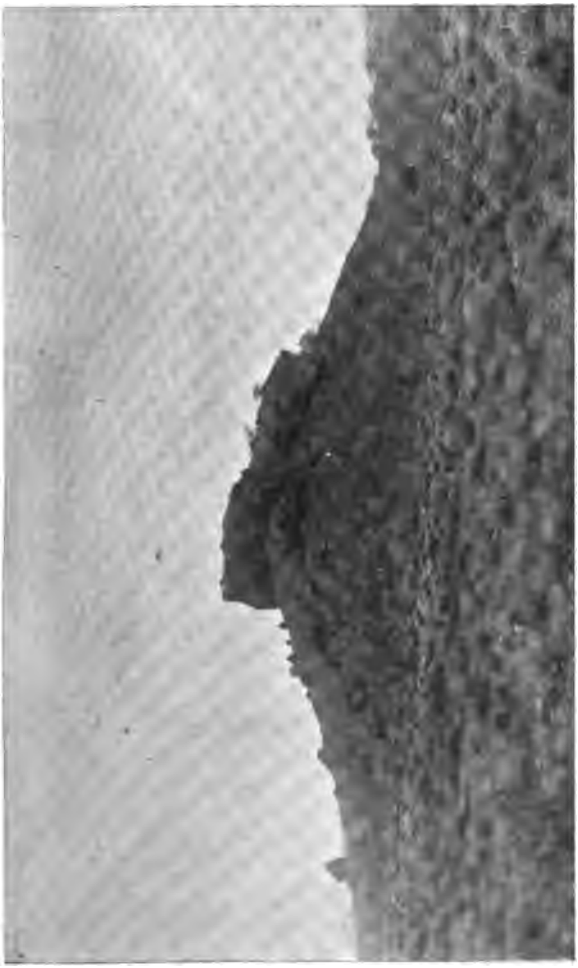

Photo: H. W. B. Talbot. Neg. 1503

HANN TABLE-TOP.—A Butte lying off the Hann Breakaways. Note encircling Talus-Slope.

We believe that, had not the variable winds of this region (see p. 42) piled the sand against one side or other, the patches of breakaway country, whether large or small, would be surrounded by cliffs. That the buttes *are* completely cliff-girt is due to shelter afforded on the windward side by neighbouring breakaways.

2. Salient Features of mature Breakaway-Country.—The resemblance of such typical mature Breakaway-Country as the

Fig. 16.

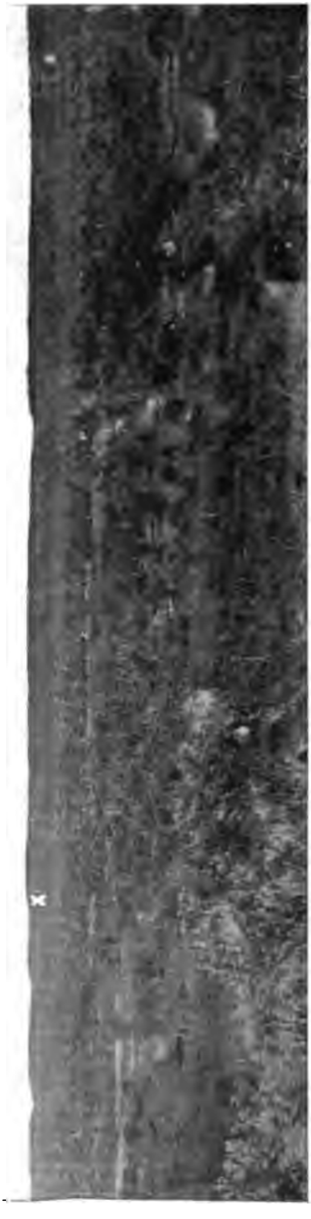

Photo: E. de C. Clarke. Neg. 1470.

SOUTH END OF WILKINSON RANGE.—From near Lily Rock-Hole. Many glaciated boulders at foot of Breakaway under X.

Hann Breakaways (Fig. 17) to a broken coast-line, the sea being represented by the flats skirting the base of the breakaways, outlying islands by mesas and buttes, is at once apparent and makes evident the appropriateness of the term "Point" applied by Mr. Hann to the more conspicuous promontories.

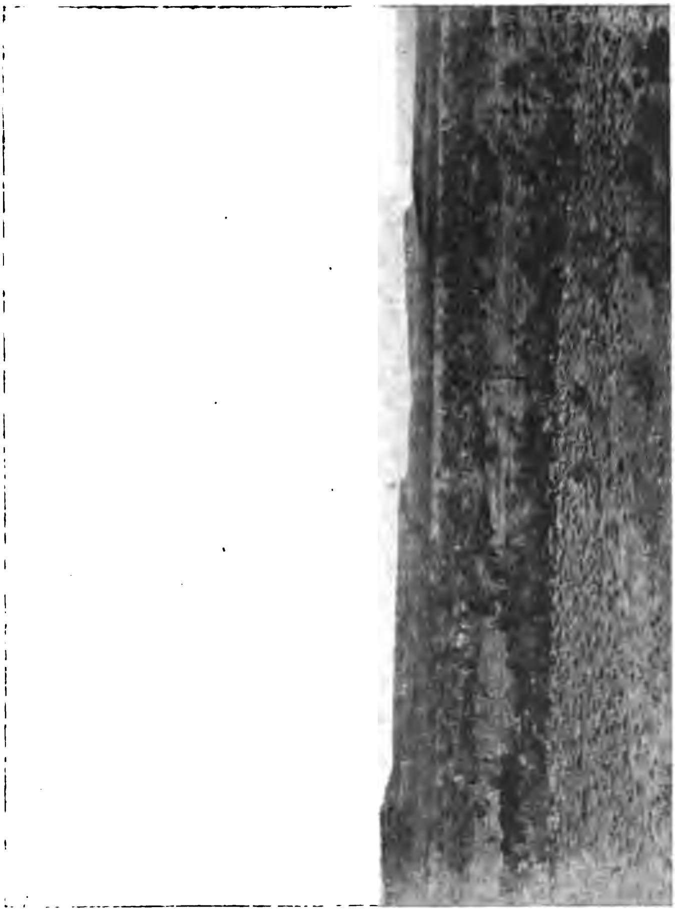

Photo: E. de C. Clarke. Neg. 1474.

HANN BREAKAWAYS.—Looking south from near Point Craig. Note irregular "Coast-line," level Fringing-Belt trenched by watercourses, and, on right, low "opposed" Breakaway.

We find ourselves, having ascended the breakaway cliffs from the fringing belt of flat country, on an almost plane surface sloping very gradually upwards from the cliff-edge and trenched by narrow steep-sided watercourses (Figs. 18 and 21). The watercourses have not penetrated far into the type of breakaway now under discussion; they enter the heads of "bays" and "gulfs" in the cliff line, sometimes at grade sometimes over a steep rock-face. The surface of this gently inclined plane generally affords very "bad travelling," being irregular in detail, strewn with boulders, and covered with a growth of gnarled and stunted "mulga," etc. Moving away from the cliffs, we probably find ourselves, within a mile or so, passing imperceptibly into sand-country. Thus a traveller approaching, for example, the Hann Breakaways from the east

Fig. 18.

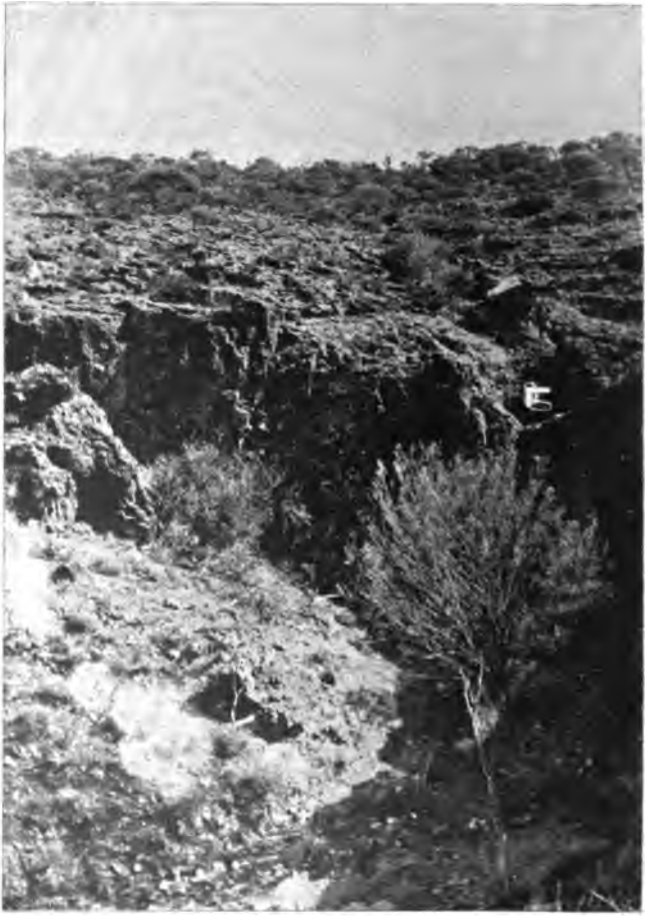

Photo: E. de C. Clarke. Neg. 1469.

LILY ROCK HOLE (L).—Note rough surface of Breakaway.

would have no inkling of their existence until, after struggling over rough, stony and scrubby ground, he found himself on the edge of low cliffs overlooking the level fringing belt.

Fig. 19.

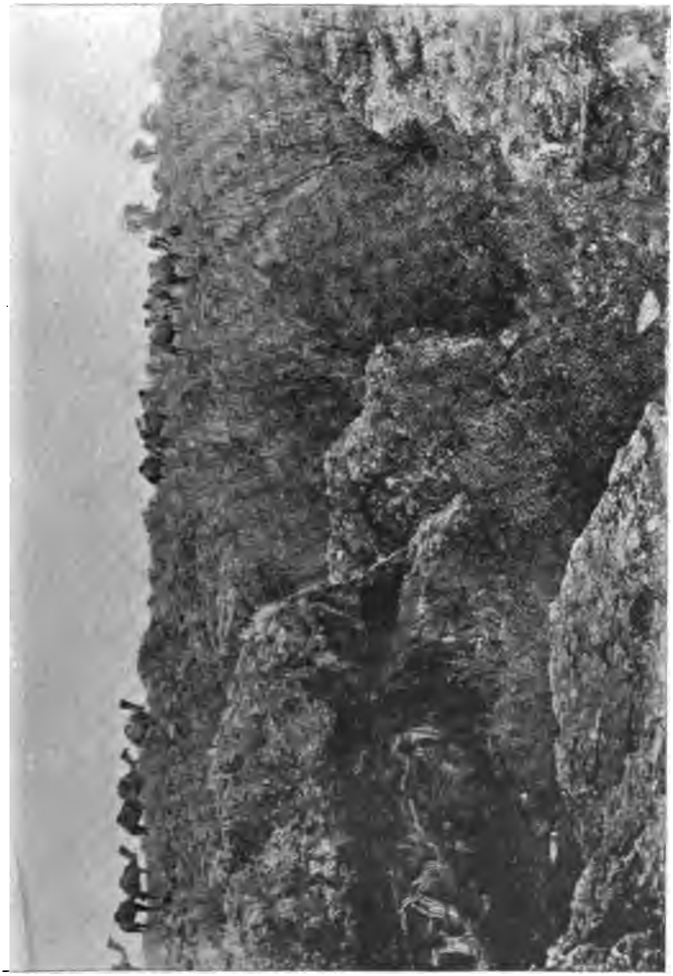

Photo: E. de C. Clarke. Neg. 1473.

ROUGH BREAKAWAY-SURFACE.—Near Point Saunders Rock Hole. Blacks' drawings on rock-face in foreground.

In places—generally near the cliff-edge—gnamma-holes occur. These are roughly cylindrical, varying in diameter and depth from a few inches to several feet, often enlarging below and thus well adapted for protection of water from evaporation (see above, page 27). Water is also held in rock-holes in the water-courses

(Figs. 18-21). It is from its function as gathering—and retaining—ground for water that Breakaway-Country is important to travelers.

Fig. 20.

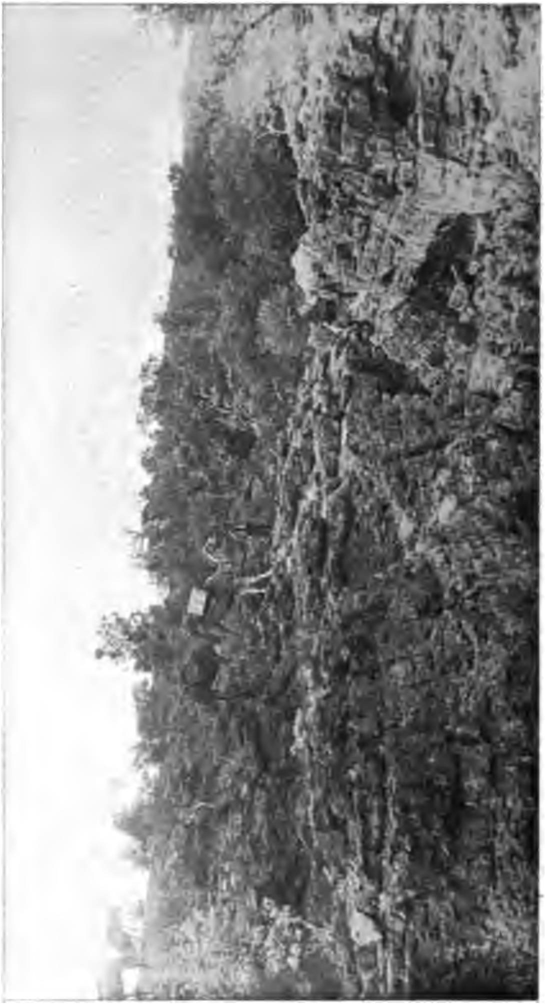

Photo: H. W. B. Talbot. Neg. 1500.

BREAKAWAY-SURFACE AT POINT LILIAN ROCK-HOLE.—Rough surface trenched by narrow gorges, 10 to 50ft. deep, in which pines grow in exceptional profusion.

Rock-holes are no doubt excavated by flood waters in the same way as the oft-described "pot-holes." Gnamma-holes such as those we saw in this sandstone country, however, cannot, despite their resemblance in shape to pot-holes, be thus explained, for their position on the sides of gently shelving patches of bare rock close to the cliff's edge precludes the idea that where they are was once a watercourse. We consider that, in the country under discussion (and we must emphasise that this is sandstone, not granite country), the gnamma-holes owe all but their initiation—as slight hollows on the laterised surface in which rain water collected—to the action of animals, including man, who, in the effort to get the last

Fig. 21.

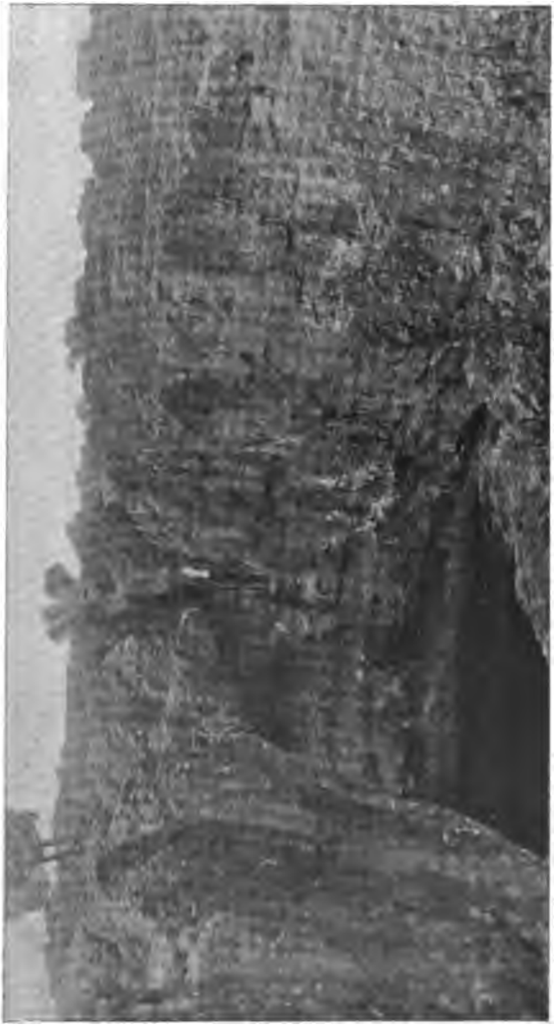

Photo: H. W. B. Talbot. Neg. 1504.

LARGE ROCK-HOLE IN HANN BREAKAWAYS.—About four miles N.E. of Featherstonhaugh Hill.

drops, scoop out the material, previously loosened by the chemical action of the water, which, particularly when low, carries a good deal of dissolved organic matter.[*]

Fig. 22.

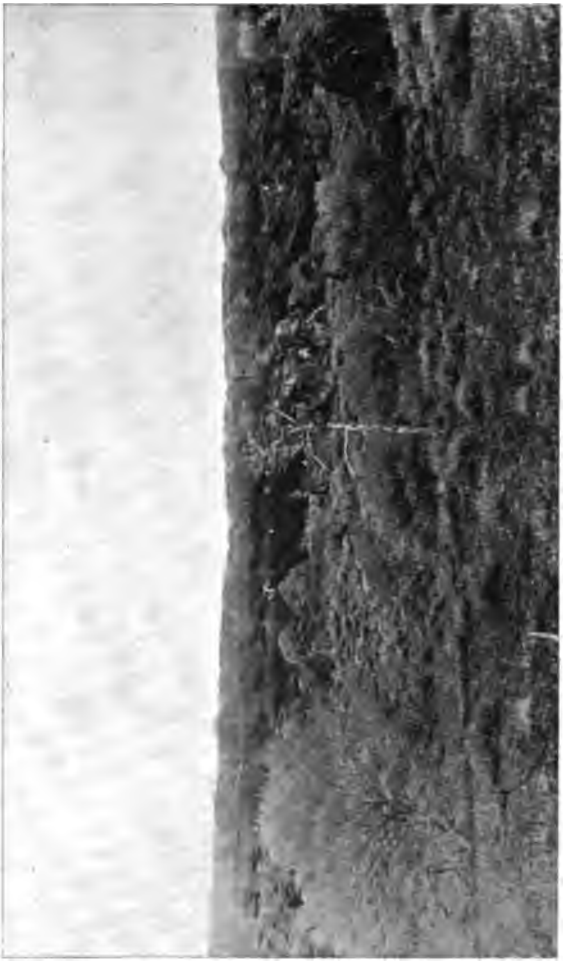

Photo: H. W. B. Talbot. Neg. 1501.

UNDERCUT BREAKAWAYS AT POINT LILIAN.—Showing entrance of caves in Fig. 23.

In contrast to the rough ground on top of the breakaways is that found on the level skirting belt (Fig. 17), which varies in width from a few chains to perhaps a mile, and separates the breakaways usually from sand-country, but sometimes from another more insignificant line of "opposed breakaways" (Figs. 12 and 17).

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[*] **Discussion of the origin of gnamma-holes in granite country will be found in G.S.W.A. Bullns. No. 45, pp. 38-9 (Talbot), No. 57, pp. 33-5 (Woodward), and No. 64, p. 116, figs. 9 and 10 (Feldtmann). See also Maclaren, Geol. Mag., July, 1912, p. 301. All these articles, however, deal with gnamma-holes in granite country.**

Though outcrops and stony patches occur on this fringe, especially near the foot of the cliffs, good travelling can generally be found, for it is, at least in part, covered with soil which supports a fair growth of mulga or saltbush and, after the heavy rains, luxuriant herbage. The fringe is generally traversed by shallow trenches cut by the more vigorous watercourses which descend from the breakaways.

Though the smaller breakaway-cliffs (say 30 feet or less in height) are nearly vertical, more than half the total height of the higher breakaways is made up of a steep, rough slope strewn with boulders of all sizes (Figs. 14 and 15). Very occasionally, where a cloud-burst has lately caused unusual scouring away of this slope, solid rock is exposed at no great depth beneath the talus.

The topmost layer (five to ten feet in thickness) of the cliffs and of the rough surface extending away from their summit is hard and resistant,* the rock having been converted into siliceous or ferruginous laterite by the deposition of silica or iron oxide drawn to the surface by capillarity. Siliceous laterite is not nearly as common as ferruginous. In granite breakaways the siliceous capping, if present, generally rests directly on weathered granite. Breakaways in the sedimentary rocks occasionally show a capping, seldom more than a foot in thickness, of siliceous laterite, beneath which there is an abrupt change into the ferruginous variety. There is no well-defined boundary between the ferruginous laterite and the underlying rock.

The laterised topmost layer, if ferruginous, frequently overhangs the basal part of the cliff, in some cases indeed pronounced caves are present. These may be on the promontories, as at Point Lilian (Fig. 22), up narrow gorges as near Point Lilian, and even in such well sheltered spots as the banks of small watercourses in thick mulga near Winterbottom Rocks. The cavities seen by us had evidently been used as shelters both by animals and man, the floors being strewn with excrement and bones. Animals generally retreat to the back of caves as it is cooler and darker there than near the entrance. To make a more comfortable resting-place they roll against, and scratch away the soft material of the floor and sides. The resultant dust is removed by wind. Aboriginals use the caves in wet weather, and remove any blocks that may fall from roof or sides.

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* It appears likely that this hardened surface-layer—belonging to no particular geological horizon—is comparable to the " Desert Sandstone " to which there are many references in reports dealing with arid parts of Australia.

The cave roof is sometimes "holed through" to the upper surface of the breakaway, the openings being gnamma-holes which have been tapped by the undercutting of the cliff.

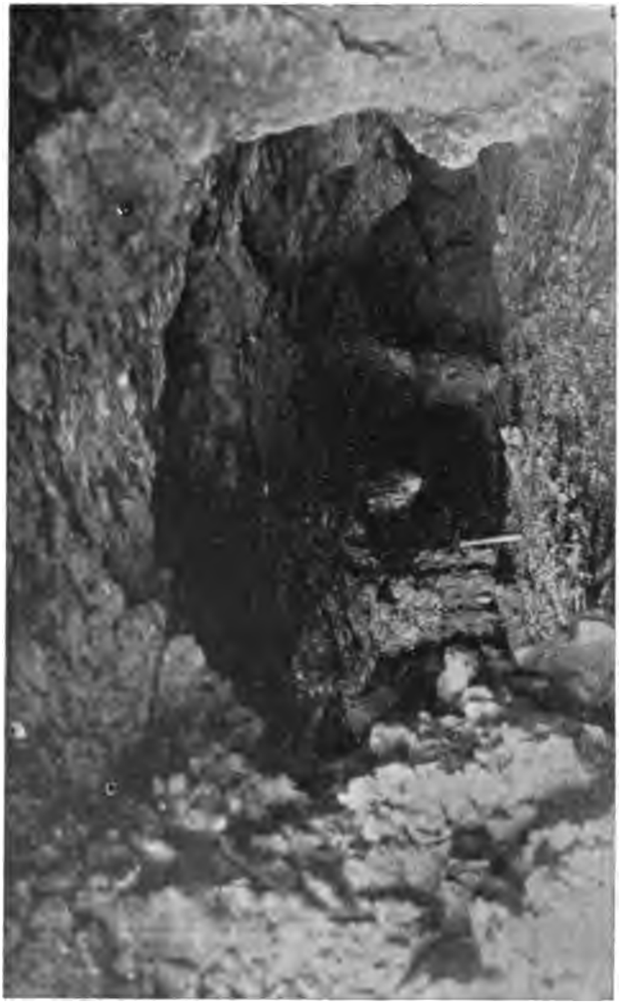

Fig. 23.

Photo: H. W. B. Talbot. Neg. 1502.

CAVE IN POINT LILIAN BREAKAWAY.—Roofed by laterized sediments

It is usual to find the inner wall of these cavities, unless recently disturbed, coated with a thin powdery skin which flakes off at the slightest touch. This "meal of disintegration" is, no doubt, due largely to the great diurnal change of temperature.* As the breakaway recedes by undercutting, caves which ran in from the base of the cliffs of former days may occasionally be preserved under talus. Such older caves at lower levels, with their openings blocked by *débris*, and accessible only by small chance openings, were noted particularly on the flanks of Hann Table Top and Faulkner Hill.

The preceding remarks refer to breakaways capped by ferruginous laterite; if the capping be only siliceous it is, owing to its extreme compactness and consequent susceptibility to insolation, broken up into small blocks, and does not project beyond the underlying strata.

3. **Degraded Breakaways.**—The Breakaway-Country forming Millar "Range" is divided by wide, flat-bottomed valleys, through which run ill-defined watercourses, into large, irregularly-shaped "islands" now in course of subdivision by subsidiary valleys.

Still more reduced Breakaway-Country is exemplified by Winterbottom Rocks (Fig. 24) and the many low outcrops of weathered sandstone east of Point Saunders.

Finally, in many places, when traversing the sandy country, we passed over low rises covered with gravel (Fig. 12) which represent the last stage in the erosion of breakaways, to be covered soon by the slowly shifting sand.

4. **Mode of Formation.**—It seems to us that breakaway country cannot, despite its general resemblance to a coast-line, be accounted for by marine action. If, for example, the Hann Breakaways are a line of cliffs marking approximately a former sea-margin, we should expect the Bailey Breakaways 200 miles to the west and supposedly marking a much later halt of the retreating sea to be at a distinctly lower level; but, as already noted, there is marked uniformity in general level from Laverton to the South Australian border.

Marine erosion fails also to account either for small "opposed" breakaways facing, and only a short distance from, the main cliffs (Figs. 12 and 17), or for the presence of steep cliffs and caves in the most protected places on the "coast-line," and even up the narrowest watercourses.

All the country between Townsend Range and Dunge's Hill is composed, to an unknown but probably inconsiderable depth, of horizontal Wilkinson Range beds (see below, p. 105), masked in great part by a superficial covering of sand, which occupies slight hollows cut out of the horizontal beds.

Given an initial grooving—probably in less arid times by a river-system which greater knowledge of topography of these parts may enable us to trace—agencies at present in action will account for the formation and maintenance of the breakaway type. The covering of resistant laterite—always formed over somewhat porous yet fairly solid rocks in such arid regions—protects from vertical but not from lateral erosion. Undercutting is, as explained in a preceding section, carried on by temperature changes causing flaking off of small particles, and by action of man and other animals. The wind removes the finest particles, but, as in the Hilly Zone next described, so in the breakaway country we looked in vain for satisfactory evidence that it is a corrading agent of any importance.

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* W. Cross, "Wind Erosion in the Plateau Country."—Bul. Geol. Soc. Am., Vol. 19, p. 58.

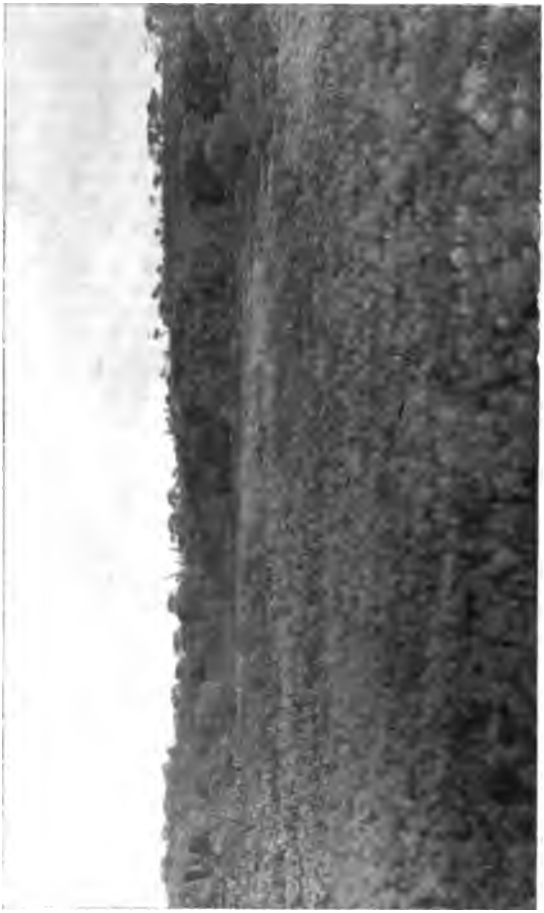


Fig. 24.

Photo: E. de C. Clarke. Neg. 1471.

WINTERBOTTOM ROCKS.—A degraded Breakaway.

The layer of laterite, though protecting the less consolidated strata beneath from vertical erosion, is itself more susceptible to insolation. Sudden changes of temperature are more likely to cause cracking in such a compact rock than in the more or less porous underlying strata in which expansion and contraction, though no doubt largely responsible for the "disintegration-meal" referred to above, are compensated for by change in the size of the pores. Moreover, the projecting portion of the laterite capping, and dislodged blocks of the same material, being exposed on three sides, are particularly liable to insolation—as witnessed by the shattering of talus-boulders and the cracking and collapse of cave roofs.

Sooner or later, then, the projecting part of an undercut breakaway collapses. The roof having fallen, the blocks lodge on or roll down the talus slope. Further reduction in size and continued transport are effected partly by variations of temperature, which cause not only further cracking but downward creep, and partly by the wash of occasional rains. Although the interior of Western Australia possesses an arid climate there are occasions on which heavy general rains visit wide areas, and even in years of drought there are usually local thunderstorms. The torrential downpours accompanying thunderstorms, and in less degree the lighter general rains, cause the talus to move downwards, the finer material being washed on to the flats which skirt the breakaways.

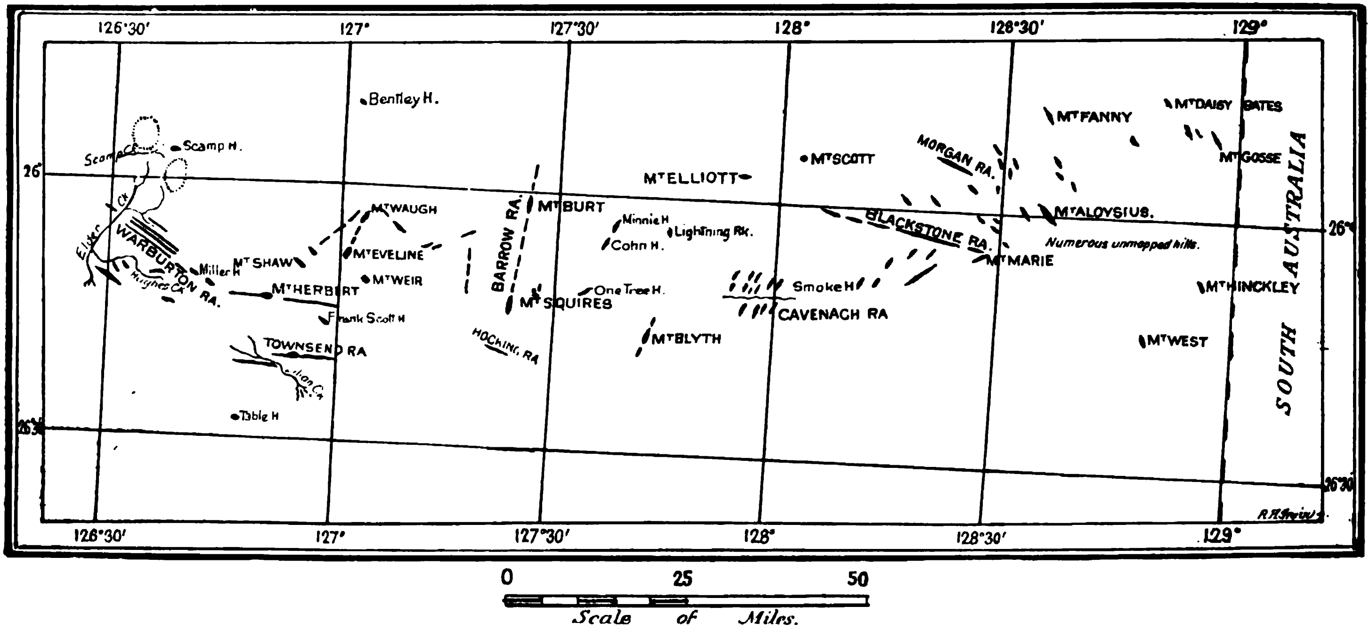
As they slowly travel away from the retreating breakaway, boulders are gradually reduced to pebbles and finally, as sand, may be "exported" by wind.

While breakaways are being cut back by insolation and animal action—these in the main disintegration agents—and by wind and water—in the main transporting agents—they are also being dissected by watercourses which isolate portions of the breakaway-country, as "table-tops," etc. The table-tops are in turn reduced to gravelly rises, and are ultimately covered—but to no great depth—with sand. It is probable that the clumps of "mulga," which apparently does not flourish in deep sand, mark the sites of vanished breakaways.

III.—HILLY ZONE.

The Hilly Zone lies approximately between latitudes 25° 40′ and 26° 20′ south, and extends eastward from the 126th meridian to the South Australian border. It may be regarded as a large peneplain, and the hills and ranges as monadnocks upon it. The peneplain has been reduced to its present condition by normal erosion, and there is no evidence that any of the elevations are due to deformation.

Fig. 25.



Plan showing distribution of Ranges and Hills in Hilly Zone.

The general height of the level ground ranges from about 1,650 feet above sea level on the flood plains of Elder Creek and Lilian Creek, to 2,100 feet to the east of Amy Giles Rocks. Mt. Aloysius rises to a height of 1,400 feet above the surrounding country, but none of the other hills visited stand more than 700 feet above the peneplain.

A.—Features of the Peneplain.

1. **Sand-Ridges.**—In the eastern portion of the Hilly Zone there are some extensive areas occupied by sand-ridges; the sand forming them being derived by weathering from acid rocks. The description given of sand-ridges in the Desert Zone applies also to those of the Hilly Zone, but in the latter region the ridges are usually much farther apart. The width of the intervening flats varies, being seldom less than a quarter of a mile and usually much more.

2. **Soil-Plains.**—Between the ranges and hills extensive plains, covered with soil, extend northward from the latitude of Townsend Range for about twenty-five miles, and eastward from Elder Creek to a few miles beyond Mt. Eveline. Between the latter point and the South Australian border there are also some large soil-plains, but here their place is often taken by sand-ridges.

The soil of the plains is principally formed by weathering *in situ* of the underlying rocks, although it is added to by silt brought down from higher ground in flood-time. There are few defined water-courses on the plains, as the streams, which rise in the ranges, usually spread out after reaching the flat country. The type of soil on the plains varies according to the nature of the country rock, ranging from rich dark loam formed by basic rocks to light, sandy soil yielded by acid rocks.

In good seasons the soil-plains support a luxuriant vegetation, but in times of drought they are even more bare than the sandy plains, as the only permanent vegetation is mulga and scrub, whereas the sand-plains carry spinifex. The rains that fall in the summer and autumn produce quite a different type of vegetation to that which follows a downpour in the colder months of the year. Rain between April and September is followed by a rapid growth of everlastings and other quickly growing annuals, but the perennial grasses and plants only sprout when they receive sufficient moisture in the hotter months. The latter type of vegetation lasts much longer than the former; it may become dry but will afford pasturage for stock for several months. The annuals, on the other hand, dry up in the first few hot days of summer and the first strong wind blows them away.

B.—FEATURES OF THE HIGHER COUNTRY.

1. **Ranges.**—The ranges in the Hilly Zone may be divided into four types:—

(a.) Long "whale-backed" ridges, with gaps at intervals, *e.g.*, Warburton Range.

(b.) Wide stony ranges, with narrow, grassy flats running through them in all directions and forming hills which, although close together, are quite separated, *e.g.*, Cavenagh Range and north end of Barrow Range.

(c.) Large dissected masses, *e.g.*, the western end of Tomkinson Range at Mt. Aloysius and southern end of Barrow Range at Mt. Squires.

(d.) Ranges with a steep escarpment on one side, and comparatively gentle slope on the other, *e.g.*, Townsend Range.

Lithological character is not responsible for the configuration of the ranges classified above, as the weathering of rocks of very different composition has resulted in the production of ranges of similar types; and, conversely, ranges varying greatly in form are found to consist of almost identical rocks.

(a) *Long "whale-backed" Ridges, with Gaps at intervals.*—Ranges of this type are represented by Warburton, Blackstone, and Morgan Ranges. The first-named is formed by a porphyry dyke, the other two by basic plutonic rocks, yet, despite their great lithological differences, these ranges agree in general configuration, being long, narrow, and flanked by rocks that are more sheared and have, therefore, been more easily eroded.

The Warburton Range is about twelve miles in length and runs north-west from Miller Hill to Elder Creek. The highest point (at Warburton cairn) is 2,320 feet above sea level by aneroid; and about 660 feet above Elder Creek. The range is formed of two parallel ridges. The depression between is not a continuous valley, but is crossed by low saddles connecting the two ridges. Creeks rise in these saddles and at intervals cut through one ridge or the other: those cutting the northern ridge flow into Warburton Creek or spread out on flats, those cutting the southern ridge join Hughes Creek.

On the same porphyry dyke that forms the Warburton Range is another shorter and lower ridge about five and a-half miles long, extending from Cassidy Hill to Mt. Herbert. Here, the dyke being narrower, there is only one ridge, which is, however, cut through in at least one place by a flat in which there is a watercourse flowing from the north to Lilian Creek. By further dissection this type passes into island-hills linearly arranged.

The Blackstone Range was only touched by us at its extreme eastern end, but we had good views of it from the north and south. It extends for nearly twenty miles in an east and west direction, and is broken in two places by broad gaps (see Plate III.). It is formed of basic plutonic rocks.

Fig. 23.

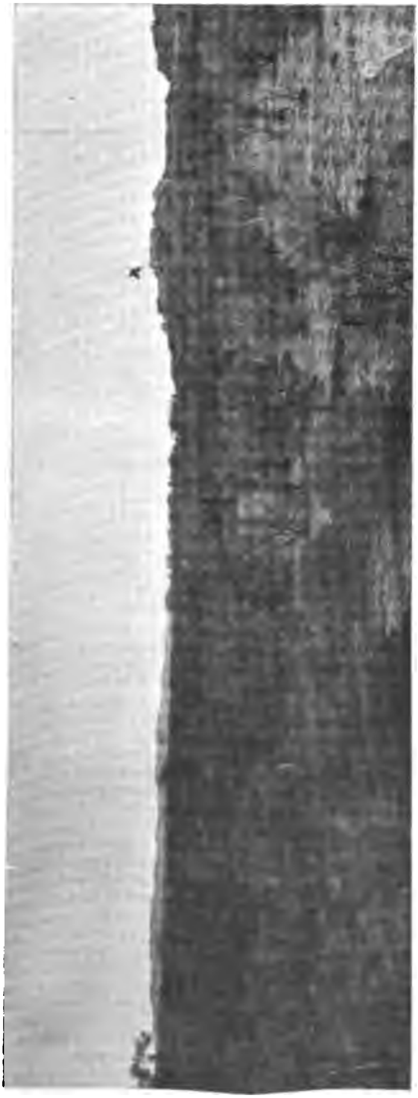


Photo: E. de C. Clarke. Neg. 1488.

CAVENAGH RANGE FROM LIGHTNING ROCK.—Rock-Hole in Fig. 10 is on near side of granite rocks at ×.

The Morgan Range is formed of the same rock as the Blackstone Range, and in appearance is exactly similar except that it is not broken by any gaps, and is very much shorter, being only about five miles in length.

(b.) *Wide Ranges completely traversed by grassy Flats.—The Cavenagh Range,* formed of basic plutonic rocks, is about seven miles across from east to west. It appeared to extend far south of our course, but its length was not determined.

Fig. 27.

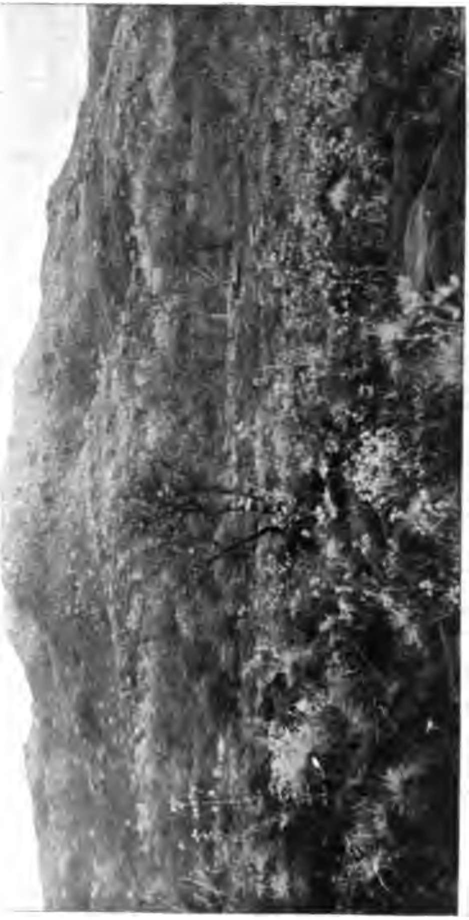


Photo: E. de C. Clarke. Neg. 1482.

FORT MUELLER, CAVENAGH RANGE.—From west, looking across Fort Mueller Creek.

Viewed from a distance (Fig. 26) the range appears to be a rugged mass of connected hills. Closer inspection shows that, while there is a remarkable absence of blind gullies, the range is completely traversed in all directions by narrow flats, usually with watercourses in their lower parts, which divide it into irregularly shaped hills of varying sizes—some probably ten miles or more in circumference. All the watercourses which we saw flow westward, and that at Fort Mueller rises east of, and runs in a remarkably straight line through, the range.

Fig. 28.

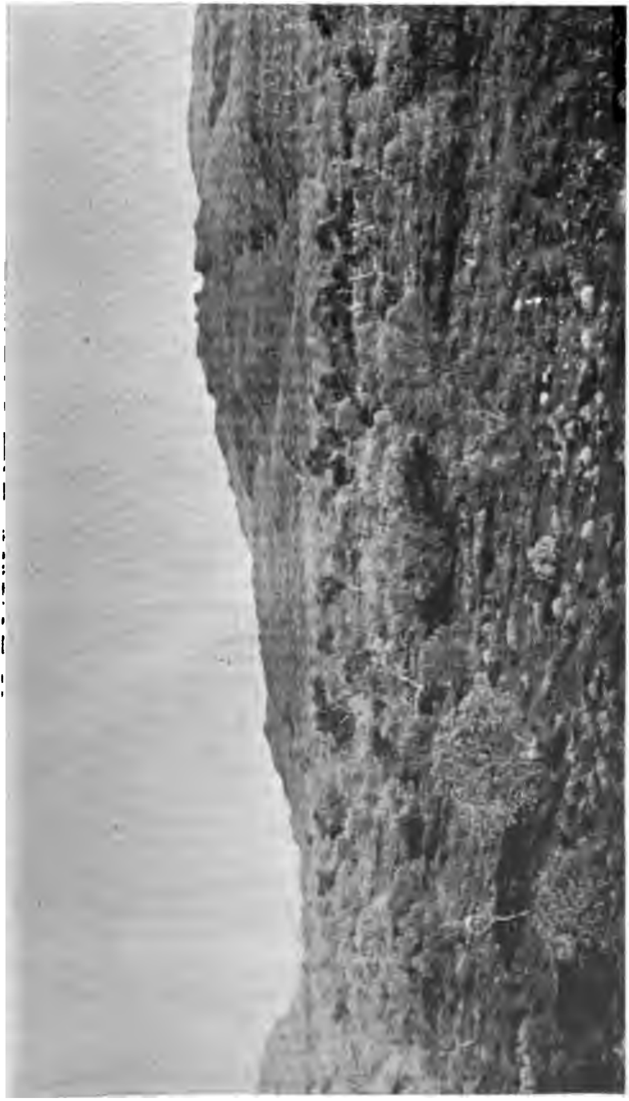


Photo: E. de C. Clarke. Neg. 1473.

FORT MUELLER CREEK.—Looking west. Giles' probable camping place in foreground.

It was noticed that, whereas the flats bordering on or entering hills of any other rock are plentifully strewn with boulders, in Cavenagh Range pebbles and boulders could only be found just at the foot of the steep slope, so that, even in narrow valleys cutting through high hills, good travelling for camels could be expected. The jointing of the basic rocks gives the precipitous upper parts of the hills the appearance of rude masonry (Fig. 29). As soon as we pass on to the gentler foot-slopes, angular monoliths are replaced by rounded boulders, which quickly diminish to pebbles and as quickly pass into grit and red soil. The upper and foot-slopes carry only spinifex, growing in clumps between the stones; the

Fig. 29.

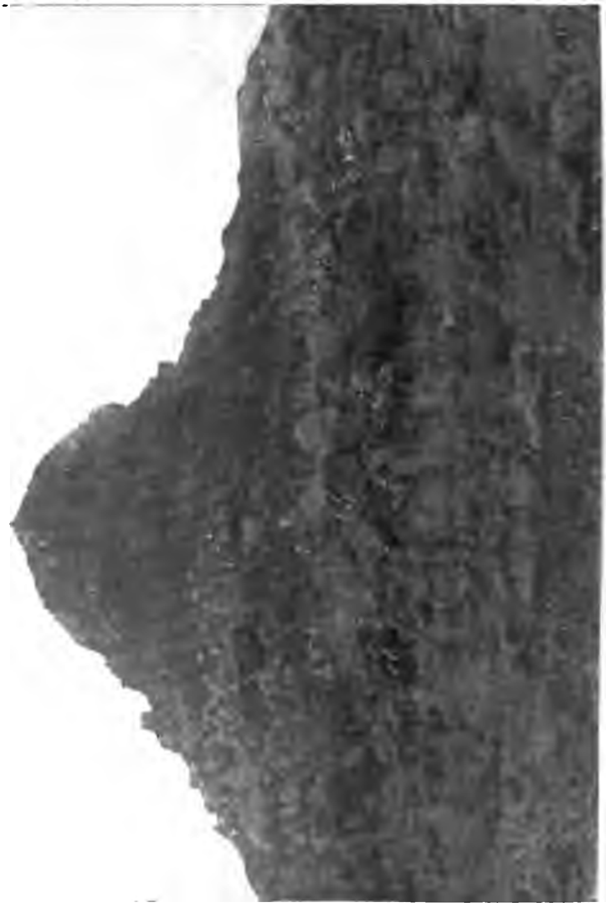


Photo: E. de C. Clarke. Neg. 1484.

CAIRN-HILL, FORT MUELLER. Forrest's Cairn was built by Hann. Note jointing of gabbroid rock.

boundary of the rough ground is thus marked by a clear line separating spinifex from the varied vegetation of the valley-floor. This sudden change is probably due to rapid chemical decomposition of the rock once it is brought under the influence of organic acids from vegetation.

Fig. 30.

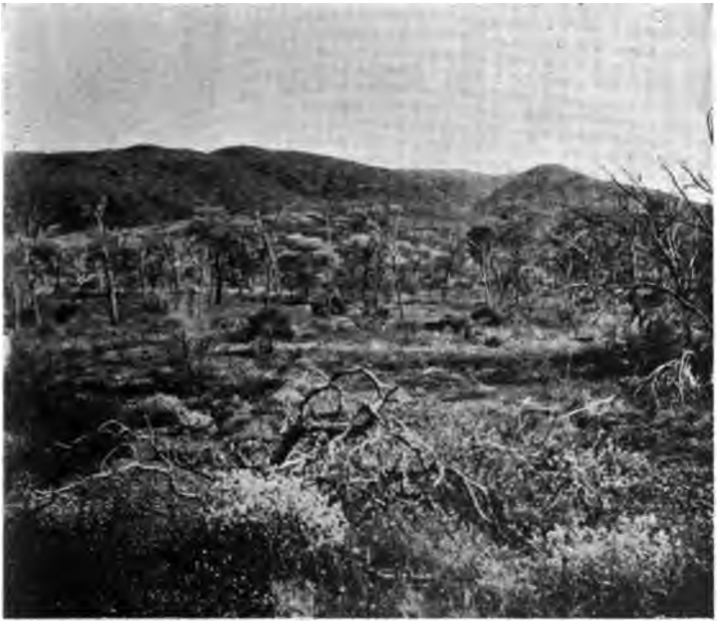


Photo: E. de C. Clarke. Neg. 1477.

Mt. SQUIRES FROM THE EAST.—A "Dissected Mass" of acid rock.

The sequence of events leading to the carving out of such features as the Cavenagh Range is probably as follows:—

Long ago, perhaps in Tertiary times, the general land-surface of Western Australia was much higher than at present, and the more resistant rocks had not yet begun to stand up as hills above those more easily removable. At that time rainfall was much heavier than now, and streams, rising in higher ground to the east, flowed west over the future site of Cavenagh Range, widening their course on both sides of it in the soft gneissic rocks, and cutting narrow gorges through the resistant basic rocks which gradually rose above the wreckage to form the present range.

Fig 31.

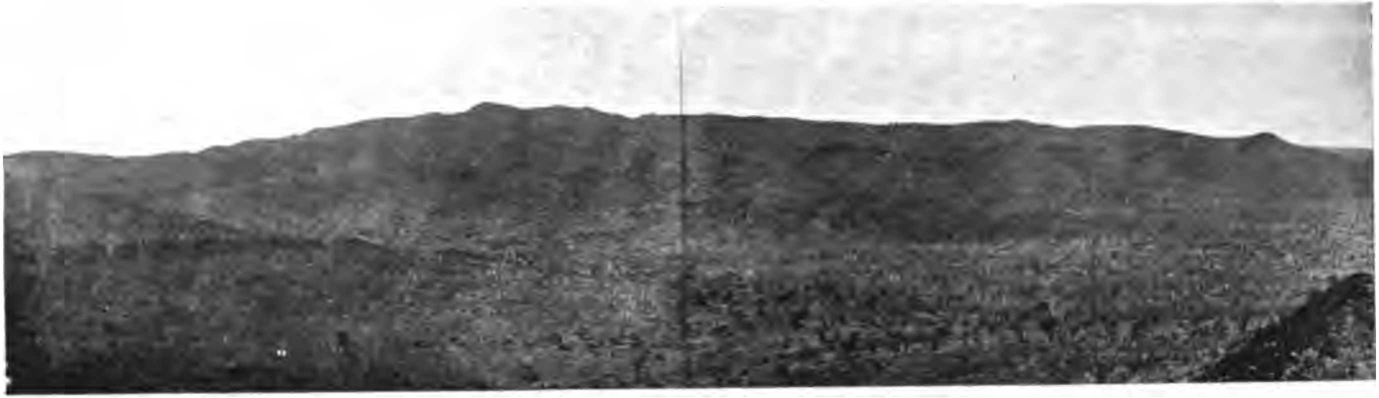


Photo: H. W. B. Talbot.

Neg. 1509-10.

Mt. ALOYSIUS FROM THE SOUTH-WEST.—A "Dissected Mass" of granulitic rock. Note dolerite dykes.

The rainfall is now only sufficient to maintain the existing watercourses against the drift of wind-borne materials.

Under present conditions insolation plays a predominant part in the slowly proceeding degradation of Cavenagh Range. The component rocks are hard and brittle, and so are very likely to crack when subjected to the rapid changes of temperature which are well known to be the rule in these regions.* It was probably the rending and falling of rocks caused by this agency which gave the noises ascribed by Giles to earthquakes.†

The *North End of Barrow Range,* which consists of acid igneous rocks, in some respects resembles Cavenagh Range. It consists of numerous isolated hills, but the intervening flats are stony and wider than those just described; moreover, the watercourses do not traverse, but rise in, and radiate out from, the range. This portion of Barrow Range is the remnant, much dissected by watercourses, of a large hilly mass like those described below.

(c) *Large dissected Masses.*—Examples of this type are the south end of Barrow Range at Mt. Squires (Fig. 30), the west end of Tomkinson Range at Mt. Aloysius (Fig. 31), and Mt. Eveline. Mt. Gosse (Fig. 32), which we saw from its base, but, owing to the attentions of the blacks, were unable to ascend, also belongs to this class, and several other hilly masses were seen from the top of Mt. Aloysius.

Mt. Aloysius, Mt. Squires, and Mt. Eveline are respectively 3,650, 2,450, and 2,190 feet above sea-level, and 1,400, 650, and 430 feet above the plain-country surrounding them. Deep gullies rise near their highest points and radiate outwards to the plain.

These masses are to be regarded as remains of some of the highlands of that remote rainy period mentioned above. Unlike the Cavenagh Range, they were even then high ground, and so determine the drainage-system in their neighbourhood instead of having a drainage-system imposed on them. High upon the southern and eastern slopes of Mt. Squires a remarkable bench-like ledge runs, at an approximately uniform level, across the spurs of the mount. A similar feature was noted on the lower western flanks of Mt. Eveline. It is also indistinctly perceived on Mt. Aloysius and in parts of the Warburton Range.

Our observations were too hurried to justify more than passing reference to these interesting features, which are probably relics of an older drainage system.

North of Scamp Creek lies an area of low rugged hills composed of granular porphyry. This rock is traversed by vertical or steeply inclined joint-planes, causing the rock to split into slabs, which usually lie edge upwards. This area, which is drained by numerous watercourses and forms an exceedingly rough bit of country, is best regarded as intermediate in character between the hill-type described in this section and that exemplified by the north end of Barrow Range.

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* See, for example, "Across Australia" (Baldwin Spencer and F. J. Gillen). Vol. 1, p. 149.

† "Australia Twice Traversed." Vol. 1, p 240.

Fig. 32.

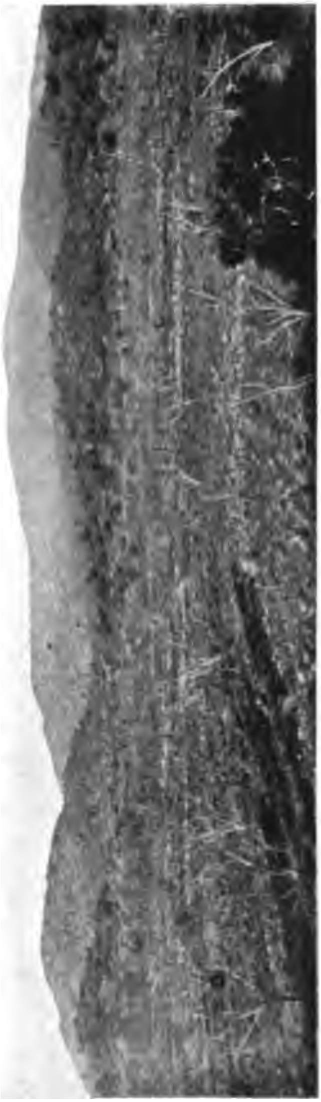


Photo: E. de C. Clarke. Neg. 1487.

Mt. GOSSE FROM THE WEST.—A ''Dissected Mass'' of gneissic granite.

(d.) *Ranges showing steep Escarpments and gentle Dip-Slopes.*—Townsend Range is the most striking representative of this group, but a low ridge of the same character runs south-east from near the junction of Elder and Hughes Creeks, and Hocking Range, which we saw only from a distance, is probably also similar.

Fig. 33.

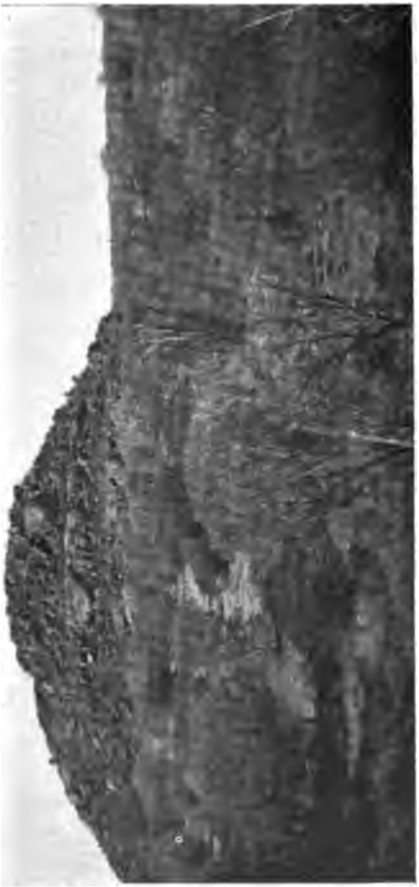


Photo: E. de C. Clarke. Neg. 1479.

LIGHTNING ROCK.—An Island-Hill in gneissic granite.

Townsend Range, in places rising over 2,000 feet above the sea and 350 feet or more above the plain-country to the north, presents a bold escarpment to the north (Fig. 8). The range is composed of hard quartzite dipping south at about 25°, this angle being approximately the slope of the southern face of the range. On the south side deep ravines cut back into the range, but, with one very notable exception, the north side is not breached by gullies. The most remarkable feature of Townsend Range is the large water-gap cut in it by Lilian Creek. The gap is about half a mile wide and is practically entirely occupied by the several ill-defined channels comprising the creek. The flat ground north and south of the range appears almost to have reached the base-level of erosion for the district, so that the creek very rarely indeed runs, and its work when it does run is confined to lateral erosion.

Fig. 34.

Photo: E. de C. Clarke. Neg. 1476.

Mt. WEIR.—An Island-Hill, really part of a dissected "Whale Back Ridge," of porphyry.

It will be noticed that the two sections of Townsend Range, which are separated by Lilian Creek, are parallel but by no means in alignment. Though there is no geological evidence on the subject, topography obviously suggests the presence of a dip-fault which Lilian Creek has followed in cutting down through the range.

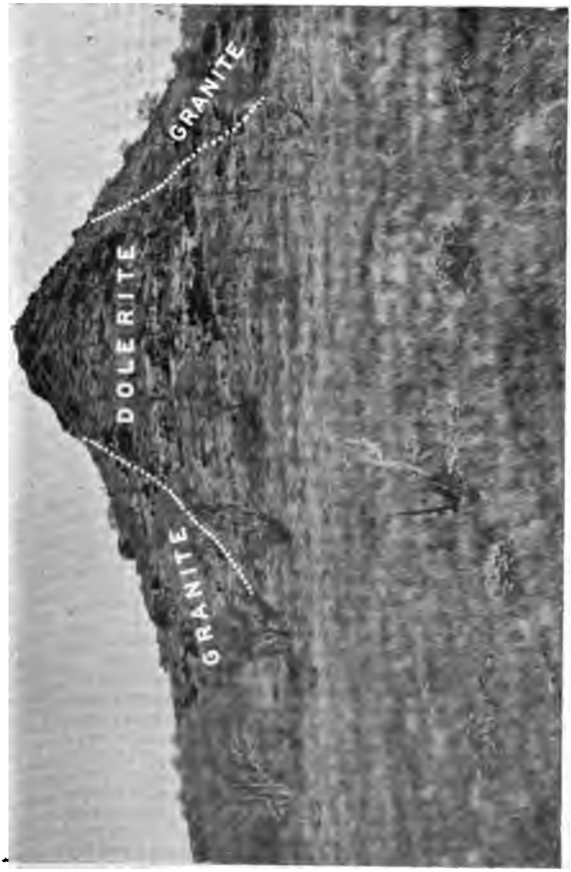


Fig. 35.

Photo: E. de C. Clarke. Neg. 1485.

DOLERITE DYKE, FORMING A KNOLL.—Hill about seven miles west of Mt. Aloysius.

2. **Island-Hills.**—Reference to Plates II. and III. shows that in the Hilly Zone there are isolated hills in all kinds of rock. They are, however, most numerous in the acidic rock areas. Few of them are more than 200 feet above the surrounding country, yet they are often visible for over twenty miles, and so make good guides for travellers, and would facilitate triangulation.

The island-hills are generally covered with more or less angular debris (Fig. 33) on which, and on the underlying rock, flaking off of fragments by insolation is the most active eroding process now in force. Downward creep, caused by changes of temperature and occasional rains, together with removal of the finest particles by wind, are the chief transport processes.

Some of the island-hills are, as already noted (p. 62), the remains of dissected "whale-backs" (Fig. 34). Isolated knobs in granite country owe their existence either to the presence of a dolerite dyke (Fig. 35) or to finer grain or absence of shearing in the granite itself (see p. 86).

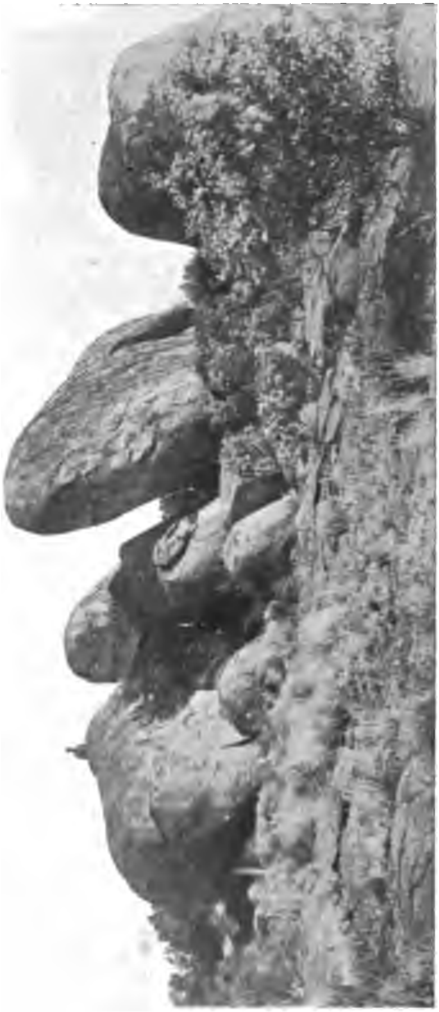


Fig. 36.

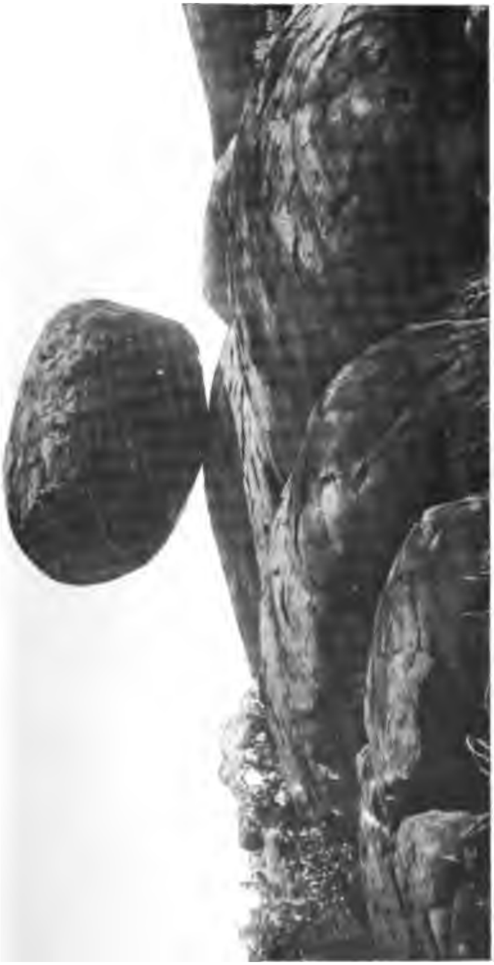
Photo: H. W. B. Talbot. Neg. 1508.

BARNARD ROCKS.—Remnants of a granite knoll.

The last stages in the degradation of these knolls are illustrated in Figs. 36 and 37.

3. **Watercourses.**—The level ground surrounding the ranges and hills has been reduced to the base-level of erosion, consequently watercourses which rise in the elevated ground soon lose their creek-like form, and spread out over the flat ground. If the creeks ran continuously, or even frequently, the water carried by them would lodge in depressions and form lakes; but they flow only at irregular intervals, perhaps not for several years.

Fig. 37.



Neg. 1507.

Photo: H. W. B. Talbot.

BALANCED BOULDER AT BARNARD ROCKS.

The water discharged on to the level ground after a drought is quickly absorbed by the parched soil, or disappears through the joints and cracks in the solid rock.

Elder Creek and its numerous branches are the most important watercourses in the Hilly Zone, but the main creek is only fifteen miles long. Above its junction with the Hughes, Elder Creek has a well-defined channel, but below the confluence it begins to spread out, and in a few miles loses its identity.

Lilian Creek is another important water channel. It rises in the hilly ground between Mt. Herbert and Cassidy Hill, flows through the water-gap of the Townsend Range, and shortly afterwards spreads out on a flood plain.

North of Townsend Range the creek has several branches, but all of them have badly defined channels, merely narrow mulga flats between low travertine rises, by which water after heavy rain finds its way to the low ground of the flood plain referred to.

Watercourses rise in all the ranges previously described, but, excepting those just mentioned, they spread out over the flat ground soon after leaving the hills in which they have their source.

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I. INTRODUCTORY.

The circumstances under which the geology of the country between Laverton and the South Australian border was examined are mentioned on p. 13.

The trip was simply a geological reconnaissance, and it must be clearly understood that the boundaries of the different formations, except where crossed by our routes, are drawn on very slender evidence, and at the best are only approximate.

The amount of possibly auriferous country in the area which we have examined is small. Information on this important subject will be found under "greenstones" (pp. 80-84), and in the chapter on Economic Geology.

A simplified and generalised account of the main geological features observed during the trip is given in Chapter I., in which also (p. 17) are defined the three sections ("Warburton Area," "Dunge's Hill—Townsend Range Section," and "Laverton—Dunge's Hill Section") into which the country examined has been divided for purposes of geological description.

II. PREVIOUS GEOLOGICAL WORK.

The geology of Central Australia, of which the Warburton Area is a part, has been dealt with more or less incidentally by all its explorers. The most important contributions to our knowledge have been made, however, by the following writers, in whose works, and in the Annual Report of the South Australian Government Geologist, 1915, references to the complete literature of the subject may be obtained:—

H. Y. L. Brown (S.A. Parl. Paper No. 45, 1890, "Report on journey from Warrina to Musgrave Ranges"), Government Geologist of South Australia, spent about three weeks in the latter part of 1889 in examining the Musgrave Ranges. Mr. Brown afterwards wrote other papers on the geology of Central Australia in which his views as to the age of the sedimentary rocks were modified.

W. H. Tietkens (S.A. Parl. Paper No. III., 1890, "Journal of Mr. W. H Tietkens' Central Australian Exploring Expedition") in 1889 travelled from Alice Springs through the Macdonnell Ranges for about 50 miles into West Australian territory between latitudes 23° and 24°, naming Lake Macdonald and the Kintore, Bonython, and other ranges. His geological specimens were briefly described by Mr. H. Y. L. Brown (*loc. cit.*, p. 32).

V. Streich (Trans. Roy. Soc., S.A., Vol. XVI., p. 74), with the Elder Exploring Expedition in 1891 (see above, p. 21), was the first geologist to traverse part of the Warburton Area.

Ralph Tate and *J. A. Watt* ("Report on the Work of the Horn Scientific Expedition," Part III., published 1896) made many important observations in the Macdonnell Ranges in 1894. Their work on the older sedimentary rocks is specially valuable.

H. Basedow ("Geological Report on the Country traversed by the South Australian Government North-West Prospecting Expedition, 1903," Trans. and Proc. Roy. Soc., S.A., Vol. XXIX., p. 57) examined the geology of a tract extending westwards from the Musgrave Ranges to Mt. Gosse, in Western Australia.

R. Lockhart Jack (Bull. No. 5, Geol. Surv., S.A., "The Geology of the Musgrave Ranges," etc.), in 1914, made extensive explorations in the eastern part of the Musgrave Ranges.

Further reference to the investigations mentioned above, and also to others, will be found in the detailed account of the geology of the Area.

Excepting a few observations by *V. Streich* (*loc. cit.*, pp. 91-92) on the geology of the desert-country south of our route, we have found no account of the formations occurring in the country bordering on that between Dunge's Hill and Townsend Range.

Previous geological work in country adjacent to the Laverton-Dunge's Hill section, as defined in Chapter I., is confined to *C. G. Gibson's* investigations (G.S.W.A. Bull. No. 24, 1906, "The Laverton, Burtville, and Erlistoun Auriferous Belt"), in course of which he examined the vicinity of Laverton, and also the Cosmo Newberry Ranges, the country at Mts. Shenton and Venn, and the Ulrich Range on the south-east side of Lake Wells. Further reference to Gibson's work will be made later.

III. WARBURTON AREA.

The two outstanding geological features of the Warburton Area are: firstly, the relatively large area occupied by metamorphosed acidic rocks and, in the western portion, the development of three great porphyry dykes; secondly, the prevalent east-and-west trend of the various formations, which contrasts with the general north-and-south direction of the granite and greenstone bands in the West Australian goldfields as far north as latitude 26°. In the preponderance of acid rocks and the east-and-west trend of formations, as in other respects, the geology of the Warburton Area resembles that of other described parts of Central Australia, from which, however, it differs in its comparatively strong development of metamorphosed basic rocks (greenstones) and in the importance of its porphyry dykes.

Perhaps the feature of widest geological interest is the presence of rocks of charnockite affinity now first definitely recorded from Central Australia.

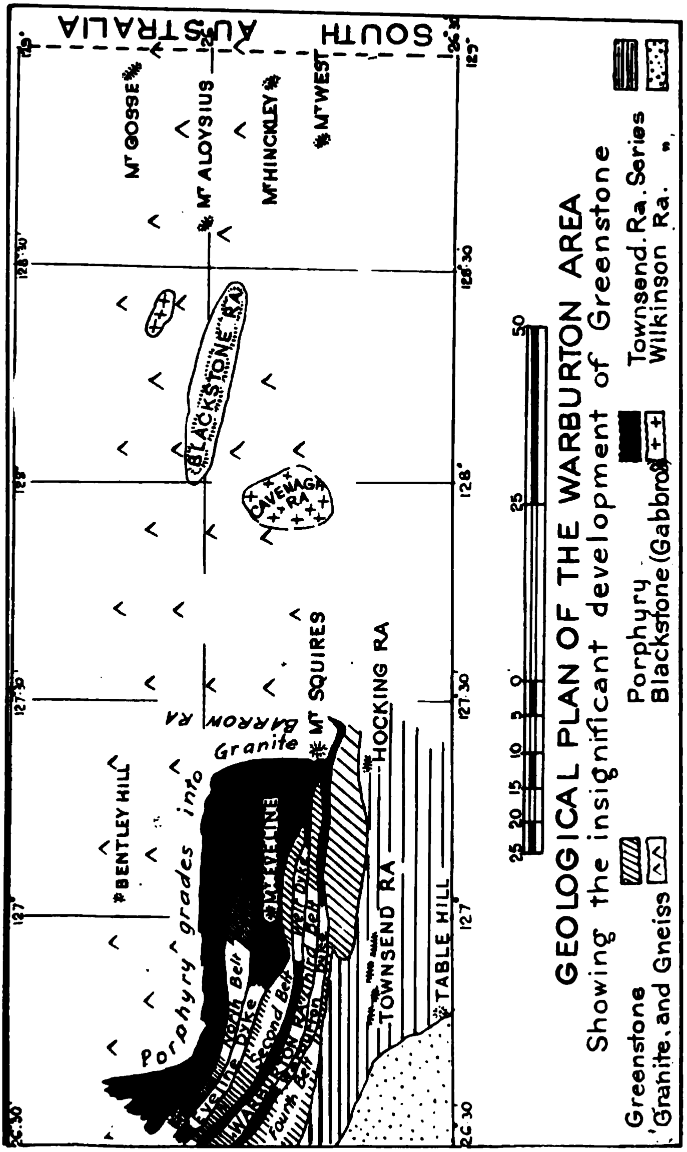
A. METAMORPHOSED ROCKS.

The rocks included under this head occupy the greater part of the Warburton Area.

1. Greenstones.

(a) *General Character and Distribution.*—The majority of the greenstones are, according to Mr. Farquharson, medium to fine-grained fibrous epidiorites and amphibolites derived from dolerites or gabbros. They have been very considerably epidotised and zoisitised, and their original augite has been almost completely altered to fibrous hornblende or to chlorite. The shear-planes by which the greenstones are traversed have a general north-west strike, *i.e.*, not parallel to the general "run of the country." The greenstones carry fairly numerous quartz veins and, as mapped, cover an area of about 406 square miles, running, as four irregular belts separated by porphyry dykes, in a direction a little south of east from Warburton Range for more than 40 miles to the vicinity of Barrow Range.* To the north they are bounded by granites and

Fig. 38.



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* We saw no greenstone in Cavenagh Range. Thomson, however (Jour. & Proc. Roy. Soc., N.S.W., Vol. XLV., p. 298), describes an amphibolite in the Streich collection "from the Cavenagh Range."

other acid rocks; to the south they are overlain by the Townsend Range series, which is probably of ordovician age.

The greenstones are like those of the West Australian goldfields, and it is the knowledge of their occurrence near the Warburton Range which has roused hopes of finding payable gold deposits there. This question is discussed in Chapter IV.

(b) *Relation to other Rocks.*—The porphyries and granites are, for reasons given in dealing with them, regarded as younger than the greenstones.

The metamorphosed sedimentary rocks and Townsend Range Series apparently overlie the greenstones uncomformably, but the former have been affected by some of the earth-movements which acted on the greenstones.

(c) *Petrology and Details of Field-Occurrence.*

(i) *First or North Belt.*—Evidence for the existence of this belt was only obtanied in two localities, and may be summarised as follows:—Travelling from Mt. Waugh to Mt. Eveline our route lay at first through a gap in the hills where no outcrops were observed. 130 chains south of Mt. Waugh we crossed a bar of dense black rock [$\frac{11}{1137}$]* with irregular patches of much lighter colour; this rock has been proved by Mr. Farquharson to be one of the greenstone series, namely, a fibrous zoisitic amphibolite. A small exposure of metamorphosed sediments (see p. 94) was then crossed, then a narrow band of a rock [$\frac{1}{1138}$] which is probably a somewhat sheared greenstone (amphibolite), then a small porphyry dyke (see p. 91), after which epidote-quartz greenstone like that described below outcrops, until we pass on to the Eveline porphyry dyke (see p. 92).

Again, near the north-west corner of the area the character of the debris, including boulders of lustre-mottled amphibolite, in the upper part of Johnson Creek and near Camp 45, indicates the presence of greenstones. There is, indeed, no evidence to justify the linking up of these occurrences with those near Mt. Waugh into a continuous belt. This, however, we have done because it is of practical importance to indicate, however faultily, the possible extent of the greenstones, *i.c.*, of "likely" country.

It is necessary here to call attention to the difficulty regarding specimen [$\frac{1}{1070}$] which is dealt with on page 98.

(ii.) *The Second Belt* extends from Elder Creek to an undefined point about ten miles east of Mt. Weir. How far west of Elder Creek it mignt be traced is not known.

The greenstones of this belt, where not close to porphyry dykes, are generally rather coarse-grained, and, in the field, show clear evidence of shearing. Near Camp 42 particularly, they often project above the general ground-level in great up-ended sheets. Specimen [$\frac{1}{1040}$] from this neighbourhood is described as a coarse-grained fibrous epidiorite. The same bar of rock is seen again at the junction of Johnson and Elder Creeks.

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* Petrological descriptions of most of the specimens referred to by registered number will be found in Appendix A.

Near the porphyry dykes, which bound this belt to north and south, the greenstone is very fine-grained and carries many small quartz veins and much epidote, *e.g.*, [$\frac{1}{1083}$].

(iii.) *Third Belt.*—The map shows this extending from Elder Creek to the south end of Barrow Range. It could probably be traced farther at its west end.

East of Miller Hill the greenstone of this belt is apparently almost entirely a very fine-grained highly epidotic rock, *e.g.*[$\frac{1}{1046}$] in many places studded with irregular blebs of quartz up to half-an-inch in diameter. Here, and also in the Second Belt, the fine-grained phase of greenstone appears to result from contact metamorphism by the intrusive porphyry dykes, for, a short distance away from the intrusion, the greenstone has graded into the typical rather fine-grained zoisitized and chloritised dolerite[$\frac{1}{1044}$] in which there are occasional bars of the very fine-grained variety.

Massive rocks, similar to that just mentioned, were noted frequently on the left bank of Warburton Creek as far down as our route followed it. On the right bank is exposed a dull-green, soft, slaty rock. A specimen [$\frac{1}{1048}$] is described as "a fine-grained finely foliated, slaty, chlorite schist."

In some parts of the Western Australian goldfields rocks like [$\frac{1}{1044}$] and [$\frac{1}{1048}$] have been proved to be merely different phases of the same rock-mass,* and those found along the Warburton Creek, although occurring so close together as to leave very little room for intermediate stages, must be similarly regarded as mere varieties.

(iv.) *Fourth or South Belt and Frank Scott Hill.*—To map, even approximately, the boundary between the greenstones and the base of the Townsend Range Series of sedimentary and volcanic rocks would necessitate more detailed examination of the rocks of the Lilian Creek Basin than we could attempt. Moreover, the basal members of the Townsend Range Series are easily mistaken for greenstones, so that, to fix the boundary, a large suite of specimens would have to be microscopically examined.

Rocks assigned to the greenstone series outcrop on the south side of the Warburton porphyry dyke, both near Mt. Herbert (see Fig. 43 and [$\frac{1}{1123}$]) and again further to the east. In these places they are seen almost in contact with the basal beds of the Townsend Range Series, which are thought to overlie them unconformably.

Again, greenstone rubble and outcrops occur at Ainslie Hill and in the neighbourhood of Hughes Creek, where the greenstone is unconformably overlain by the Townsend Range Series. These occurrences are the only justification for the area of greenstone shown south-west of Warburton Range.

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* See for example G.S.W.A., Bull., No. 68, pp. 69–70.

A patch of greenstone, in which Frank Scott Hill is the most prominent feature, extends for about five miles in an east-north-east-west-south-west direction, and is probably overlain by the lower beds of the Townsend Range Series to the north, west, and south. Nothing is known as to its eastern limits.

Frank Scott Hill [$\frac{1}{1118}$] is a massive medium-grained greenstone (a chloritised and zoisitized uralitic epidiorite), but it is bordered by chloritic slate like [$\frac{1}{1048}$] for a distance of about 20 chains to the east-north-east. The only other outcrops observed in our five-mile traverse across this patch were of fine-grained epidote-quartz rock, like that mentioned above.

(d.) *Correlation.*—A comparison of the Warburton greenstones with those of the Western Australian Goldfields and comments on the relative abundance of these rocks as compared with the Central Australian country to the east will be found in Appendix A, pp. 146 and 147.

(e.) *Economic Possibilities.*—These are discussed in the next chaper.

2. Acid Plutonic and Dyke-Rocks.

(a) *General Character and Distribution.*—Our conclusions, which, as in the case of the Greenstones, are based on meagre evidence, may be thus summarised:—

Of the 3,000 square miles included in the Warburton Area at least 2,200 square miles are occupied by acid rocks, the eastern part of the area being composed, in the main, of acid plutonic rocks which appear to send off westward great dykes, and thus separate the greenstones into the "belts" just described. The margin of this great acid plutonic batholith is finer grained than the inner portions. This marginal phase thus approximates in petrological character and general appearance to the porphyry dykes, but differs from them in its granular structure and in being generally destitute of phenocrysts. Again, two types of *plutonic* rock were recognised in the field—one characterised by its pink, the other by its grey colour—the pink variety being generally found only near the granular porphyry margin. The acid plutonic and dyke rocks have been in different places very differently affected by dynamic metamorphism; in some (particularly the dyke-porphyries) dynamic strain can be detected only with the aid of the microscope; in others intense shearing with abundant development of garnets is obvious to the naked eye.* It is in such zones of intense deformation that the rocks of charnockite affinity were found. However, in spite of the differences between extreme types, intermediate types connecting these extremes have been found, and we are forced to conclude that the acid plutonic and dyke rocks originated from one mass of molten rock as uniform in composition as such a great mass could be expected to be, though possibly the dyke-porphyries welled up a little later than the other rocks of the group.

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* The strike of the shear-planes in these areas of intense shearing is approximately north and south (see below p. 89). We have not sufficient observations to justify the assertion that all major shear-planes have this strike.

In several localities, *e.g.*, Warburton Cairn, Mt. Squires, Lightning Rock, and Mt. Scott, the presence of magnetic minerals was indicated by a slight variation (less than 3°) from the normal readings of the compass.

(b) *Relation to other Rocks.*—That the porphyritic members of the series under discussion are intrusive into the greenstones is fairly evident from their course on the map. It was noted, moreover, that the dykes (and also the great gneissic mass to the east and north) become finer grained and pink in colour as their contact with the greenstones is approached, while quartz veins and other signs of thermal metamorphism in the greenstones are most abundant near the porphyries.

Presence of porphyry fragments, identical in micro-structure with the porphyry dykes, in the basal beds of the Townsend Range Series, indicates a Pre-Ordovician age for these dykes.

(c) *Petrology and Details of Field-Occurrence.*—The acid rocks may, for descriptive purposes, be divided into—

(i) Granites, gneisses, and granular porphyries.
(ii) Porphyry dyke-rocks.

(i) *Granites, Gneisses, and granular Porphyries.*—These rocks are the predominant formation in the eastern and north-eastern parts of the Area. A good deal of the tract mapped as granitic or gneissic is obscured by sand and other superficial deposits, of which, however, there is no great thickness. On the other hand, rocks of this group form, in Mounts Aloysius, Gosse, and Squires, some of the most conspicuous hills.

The granites, gneisses, and granular porphyries vary more in field appearance and megascopic characters than microscopically. For convenience of description they may be divided into—

A. Pink Granites, Gneisses, and granular Porphyries.
B. Grey Granites and Gneisses.

A. Pink Granites, Gneisses, and granular Porphyries lie on the outer edge of the great mass of acidic rock, between the grey granites and greenstones. They vary greatly in coarseness of grain. The finest grained varieties (granular porphyries) occur on the outer (southern and western) margin of the acidic rocks, becoming coarser as we travel north and east. On the east side of Mt. Squires dyke-porphyry (like the rocks described later in (ii)) is apparently intercalated between two areas of pink granite, and would thus seem to be a dyke in the latter rock. This would, of course, make the dyke-porphyries younger than the granites; but this one, hastily-noted occurrence cannot outweigh the strong resemblance between dyke-porphyries and granites disclosed by the microscope. It can only, until more detailed work is done near Mt. Squires, be allowed to suggest the possibility that the dyke-porphyries were a slightly later up-welling from the reservoir which supplied the other acid rocks.

The granular porphyries are coarsely jointed and form rough hilly country in which serviceable rock-holes are very unlikely to occur.

They have been mapped in the same design as the dyke-porphyries, thus emphasising their porphyritic character, although they might with equal propriety have been depicted like the coarse-grained granites into which they gradually pass.

The granular porphyries have their chief development in the north-west part of the Area, *e.g.*, [$\frac{1}{1061}$]. [$\frac{1}{1068}$].

In places—*e.g.*, a little more than five and a half miles south-west of Camp 44 [$\frac{1}{1059}$] and about five miles north of Camp 42 [$\frac{1}{1057}$]—the granular porphyry is very strongly sheared and, garnets being very abundant, the rock becomes a garnet schist. It may be noted that garnets are frequently but not invariably present in the granular porphyries.

The granular porphyry belt narrows very much about six miles north-west of Camp 67, but widens to at least four miles to the north of Mt. Waugh, from which neighbourhood [$\frac{1}{1136}$] was obtained.

The coarser grained pink granites, etc., are, as already stated, found north and east of the finer grained rock. They weather into more rounded knobs than the finer grained rock and form less prominent features, but, owing to their less jointed character, are favourable country for rock-holes.

That the finer and coarser grained pink rocks grade into one another was particularly noticed at the north-west end of the Area, where, after passing over fine-grained rock (like [$\frac{1}{1061}$] above), the country becomes coarser, and a belt of medium-grained pink granite [$\frac{1}{1064}$] is entered. The rock [$\frac{1}{1131}$] five and a half miles west-south-west of Camp 68 is very similar. It is traversed by small quartz veins of two kinds—one, of a very glassy quartz, runs parallel to the foliation planes, the other, carrying pink felspars (and so presumably pegmatitic), at right angles to them.

Farther east the medium-grained gives place to a very coarse pink, somewhat granulated granite [$\frac{1}{1066}$] and [$\frac{1}{1132}$] in which, however, a fine-grained granular porphyry phase [$\frac{1}{1067}$] was found near Camp 44.

The same passage of coarser, pink, granitic rock into granular porphyry was observed between Bentley Hill and Mt. Waugh.

The country round Bentley Hill is a coarse foliated granite, like [$\frac{1}{1132}$], but the rock [$\frac{1}{1133}$] from the hill itself is a much finer grained pinkish-grey, partially granulated granite.

Again, the numerous hillocks south of Bentley Hill owe their existence to the fact that they are composed, in some cases, of dolerite, in others of a finer, more compact phase [$\frac{1}{1134}$] of the coarse granitic rock which constitutes the surrounding lower ground.

Travelling still farther south the granite becomes gradually finer in grain from a point about six miles north of Mt. Waugh, until we reach the belt of finer granular rock from which [$\frac{1}{1136}$ described above, was taken.

From the neighbourhood of Mt. Squires further evidence of the passage of fine granular porphyry into coarser pink rocks was obtained, but, as the geology of this part also elucidates the relation of all the granular, granitic, and gneissic rocks to the dyke porphyries, it will be described later.

B. Grey Granites and Gneisses.—Two types are recognised in the grey-rock area—granitic gneisses coarse in grain, not markedly foliated nor always garnetiferous, and finer grained, strongly foliated rocks rich in garnets.

The coarser grained rocks form the bulk of the grey-rock area. Most of the country thought to be composed of these coarse rocks is masked by superficial deposits of inconsiderable depth, through which the underlying rocks project as low hills and knobs. Typical examples of these rocks are described in Appendix A from Lightning Rock (where a vein six inches wide, composed entirely of microcline, was noticed), the neighbourhood of Mt. Scott, Camp 55 (Barnard Rocks), hills west of Mt. Aloysius, Amy Giles Rocks, and from Mt. Gosse. Combining Mr. Farquharson's descriptions with our field notes, we may summarise the characters of these "coarser grained" grey rocks by stating that their colour is nearly always grey; that though often coarse, and at Mt. Gosse and Amy Giles Rocks sometimes exceedingly coarse in grain (Fig. 39), they can in many places be seen to change from coarse to rather fine in a very short distance; that they show usually in the field in their banded structure, etc., and invariably under the microscope, in granulation, irregular optical properties, etc., evidence of having undergone dynamic metamorphism; and that they are best called biotite-microcline granitic gneisses.

Finer grained garnetiferous rocks were recognised in the vicinity of Cohn Hill, on Mt. Aloysius, and about half-way between Amy Giles Rocks and Mt. Gosse.

Cohn Hill is composed of highly garnetiferous, strongly sheared rocks whose foliation planes dip west at about 70°, and which are cut by a dolerite dyke. One of the specimens [$\frac{1}{1008}$] collected at Cohn Hill is described by Mr. Farquharson as "a finely foliated and banded garnetiferous granitic gneiss."

Specimen [$\frac{1}{1005}$], also from Cohn Hill, corresponds generally to the granulite from this neighbourhood described by Streich and

Stelzner,* but is more exactly a garnetiferous hypersthene gneiss or granulite strongly resembling metamorphosed varieties of charnockite.

Fig. 39.

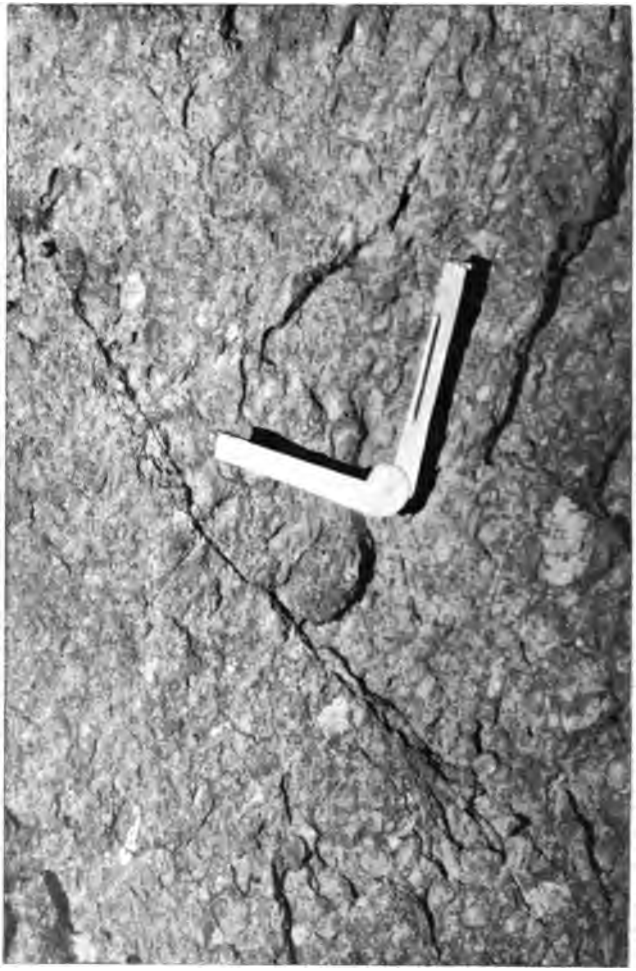

Photo: E. de C. Clarke. Neg. 1486.

COARSE SHEARED GREY GRANITE.—At Amy Giles Rocks. Arms of rule are six inches long.

Debris from the foot of Minnie Hill resembles the Cohn Hill rocks, which, therefore, probably extend thus far to the north.

Streich † classes "this granulite as a part of the formation of the Townsend Ridges, of which it may represent a lower stratum." However, in view of the much larger occurrences of similar rocks at and near Mt. Aloysius, we have little hesitation in regarding the granulite as a special phase of the grey granites and gneisses.

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* Trans Roy Soc., S.A. Vol. XVI., pp. 83 and 111.
† Loc. cit., p. 83.

Mt. Aloysius, rising 1,400 feet above the surrounding country, is composed of strongly foliated garnetiferous porphyry [$\frac{1}{1112}$] or granite containing sillimanite in [$\frac{1}{1111}$], which is penetrated by dolerite dykes. The foliation planes run in general south-east or south-south-east, but follow a rather sinuous course (see Fig. 40).

Fig. 40.

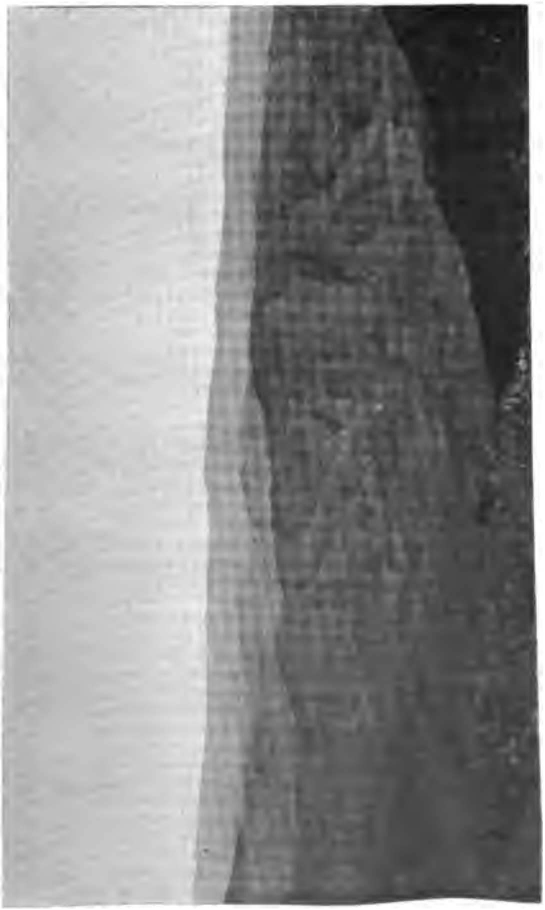


Photo: H. W. B. Talbot. Neg. 1511.

LOOKING S.E. FROM TOP OF Mt. ALOYSIUS.—Foliation of gneiss clearly seen to distance of two or three miles.

Outcrops, noticed at intervals for seven or eight miles east of Camp 58, amongst the sand-ridges and on the mulga-covered flats indicate that the underlying rocks are mainly fine, strongly foliated, garnetiferous gneisses (in some places almost schists) like [$\frac{1}{1114}$].

C. Comparison of pink Granites, Gneisses and granular Porphyries with grey Granites and Gneisses.—The microscopic and field-characters of these two sub-groups may be summarised as follows:—

Pink Granite, Gneisses and granular Porphyries.	Grey Granites and Gneiss.
1. Coarse texture (giving place occasionally to much finer). Reddish or flesh-coloured.	Same in all but colour.
2. Belts showing gneissic banding or foliation in the field are succeeded by belts from which this feature is absent.	Same.
3. Felspar mostly microcline ..	Same.
4. Occasional flakes and aggregates of brown biotite	Flakes of brown biotite occasionally.
5. Brownish-green hornblende crystals occur, but only rarely	Brownish-yellow hornblende crystals occur occasionally.
6. Irregular extinction in quartz and felspar; irregular lamellation or disintegration of felspar and quartz plates in some cases and occurrence of small areas of granulation	Marked dynamic deformation effects such as:—Strain-shadows, irregular extinction; lamellation; granulation of quartz and felspar plates; schiller-structure in the felspars produced by pressure.
7. In a few instances coarse intergrowths of quartz and felspar	Small areas of quartz-felspar intergrowths.
8. Garnets do not appear in the more granitic rocks, but are found in the granular porphyries, more especially where they have been excessively sheared.	Small grains of reddish garnet in aggregates especially in $[\frac{1}{1113}]$. Garnets are also abundant in the strongly foliated varieties, *e.g.* $[\frac{1}{1112}]$ $[\frac{1}{1096}]$.

It is thus evident that, although the characteristic colours appear to be confined to definite areas, and might, therefore, be expected to accompany more fundamental differences, the pink and grey granites resemble one another so strongly that they must be regarded as forming one rock-mass. It will be shown later, moreover, that the pink granites, etc., are connected with the porphyritic rocks to be next described, and, therefore, that all the acid rocks form a petrological unit in which the pink granites represent a marginal phase of the grey granites and gneisses.

(ii.) *Porphyry Dyke-Rocks, usually little metamorphosed.*—The dyke-porphyries are prominent topographically in the west part of the Warburton Area, where, owing to their resistance to weathering, their course is commonly marked by lines of hills (see further p. 62). This prominence has made it possible to sketch-in three dykes, from the vicinity of the Barrow Range for about 50 miles to the west—in which direction they probably persist some distance farther.

These dykes, which for convenience of reference have been named from prominent hills in them, the Eveline, Weir, and Warburton Dykes respectively, vary in width from 15 to 260 chains, and show a rough parallelism to one another and to the edge of the "Pink Granites." Their course is sufficiently indicated on the map and needs no further comment except that the topography of the country west-north-west and north-west of Miller Hill, which we did not traverse, may indicate rather branching than widening of the Warburton Dyke.

Viewed in mass in the field the dyke-porphyries show jointing but (except on Kathleen and Bob Hills) no shearing. Jointing is particularly noticeable in the Warburton Dyke near the Warburton Cairn.

With a few interesting exceptions these rocks show a general agreement in mega- and microscopic characters. In hand specimens they are grey, brown, or black rocks, with very fine-grained groundmass, in which lie phenocrysts, sometimes of pinkish felspar, sometimes of quartz (which is often bluish), sometimes of both minerals. Small grains or crystals of pyrite are not uncommon. Under the microscope signs of dynamic metamorphism can always be detected, though they are not always very noticeable. Occasionally, an approach to granophyric structure was observed. Besides the ever-present quartz and felspar small garnets were noted in the strongly sheared [$\frac{1}{1140}$] from Kathleen Hill. Generally speaking then, the dyke-porphyries are either quartz or felspar porphyries which grade into one another.

In addition to specimens from the well-defined Eveline, Weir, and Warburton dykes, rocks not suspected of being porphyries were collected in three localities.

Of these [$\frac{1}{1139}$] from about two miles north-north-east of Kathleen Hill, which was taken to be a metamorphosed sediment, proves to be a sheared porphyry. Its course, as a small independent dyke, is very doubtfully sketched, solely by topographical features and not by tracing its outcrop in the field.

Again, [$\frac{1}{1106}$] found outcropping along our route for about a mile to the east of Camp 55, was thought to be a fine-grained basic rock, but is proved by Mr. Farquharson to be a fine-grained, flinty, sheared porphyrite, *i.e.*, a rock of different type to any of the porphyries described above. Its field-relations to the granite and gabbro mapped to the north and south were not determined.

Lastly, there is the same absence of field-evidence about [$\frac{1}{1102}$] from one of the many scattered outcrops of similar rock on the red soil flats about 6½ miles north-east of Fort Mueller. This rock was also taken to be a fine-grained basic rock in the field, but proves to be a fine-grained, felsitic quartz-porphyry.

(iii.) *Relation of granitic to porphyritic Rocks.*—The field and microscopic evidence outlined below, indicates that the granites, gneisses, and granular porphyries (described in (i.) above) and the dyke-porphyries (described in (ii.)) originated from the same magma. This evidence is, perhaps, best set out under two heads:—

Dyke-porphyries are seen passing into granular porphyries:—

At North-West end of Eveline Dyke: The rock found about 20 chains west of Camp 45 is porphyry like [$\frac{1}{1055}$]. This passes, along no definite boundary, into a rock [$\frac{1}{1074}$] which has the external appearance of a rusty, sheared greenstone, but which, in less weathered parts, looks like one of the granular porphyries, and proves under the microscope to be a fine-grained very sheared quartz-porphyry. A little more "mashing" and this rock would be classed as one of the granular porphyries.

Near Camp 67, in Eveline Dyke: The bulk of the dyke is made up of granular porphyry, [$\frac{1}{1128}$] and [$\frac{1}{1125}$], but small occurrences of the ordinary porphyry were also seen.

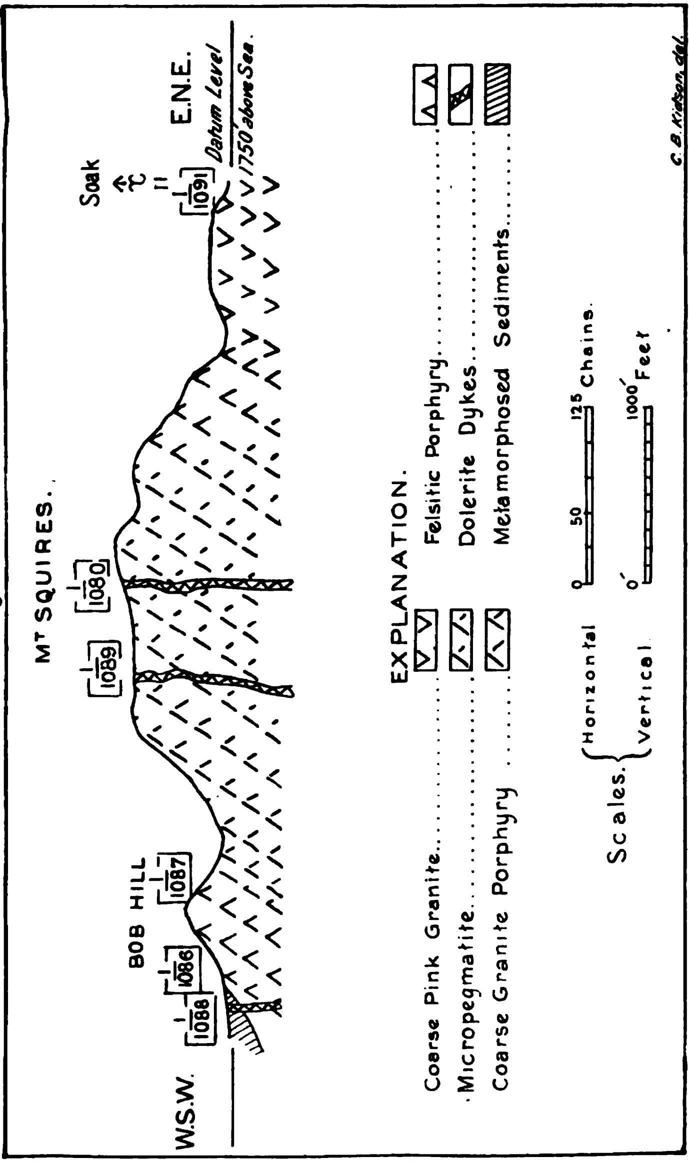
Dyke-porphyries are seen passing into granites:—

Near Mt. Squires (see Fig. 41). Travelling eastward, before reaching Bob Hill, the country appears to be an eastern extension of the Warburton Dyke, in which occurs a felsophyre phase [$\frac{1}{1086}$]. On the western slopes of Bob Hill there outcrops a porphyry of the usual type for dykes of the Warburton Area, in which, however, weathering discloses an unusual, fine foliation. This porphyry can be seen to grade in about 20 yards into [$\frac{1}{1087}$] which, though to all appearances a coarse granite, is nevertheless proved by its micro-structure no less than by its field-occurrence, to be intermediate between a granite and a quartz porphyry. This, in turn, passes into the remarkable [$\frac{1}{1090}$] (of which [$\frac{1}{1089}$] is a local variety) which, in hand-specimen, is a pink even-grained granite, but proves under the microscope to be "almost wholly composed of a micro-pegmatitic intergrowth of quartz and felspar," and is described as a micro-pegmatite almost identical with a rock obtained by the Horn Expedition (full notes will be found in Appendix A). The micro-pegmatite is apparently succeeded to the east by a porphyry dyke rock (but regarding this occurrence see above, p. 85 forming some of the foothills on the east side of Mt. Squires. Beyond this again, comes in a very coarse pink granite, of which [$\frac{1}{1091}$] is typical.

Traversing Barrow Range about ten miles north of Mt. Squires, rocks [$\frac{1}{1144}$] and [$\frac{1}{1145}$] were obtained, which are intermediate between the ordinary dyke porphyries and the very coarse granitic porphyry [$\frac{1}{1087}$], and thus confirm the very clear passage between these two types already recorded from Bob Hill.

As a rule, dynamic strain-effects are most apparent in the granites, gneisses, and granular porphyries, are less obvious in the dyke-porphyries and practically absent from the narrow parts of dykes. This seems understandable, since stresses seeking relief in east and west directions (as apparently some did in the Warburton Area) would find it more readily by re-shearing the easily-yielding already-sheared greenstones rather than by shearing the massive porphyries. Where, however, wider masses of unsheared rock lay across the lines of shearing and would necessitate too great a deflection, then this unsheared rock had to yield and be sheared.*

Fig. 41.



Diagrammatic Section through Mt. Squires, showing Transition Stages in Acid Rocks.

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* G.S.W.A., Bull. No. 68, pp. 63. 86.

(d.) *Original Character of the Metamorphosed Acid Rocks*: In Appendix A, pp. 137-146, will be found a comparison by Mr. Farquharson of the Acid, Plutonic, and Dyke Rocks with those from other parts of Central Australia, in which he concludes that the granites of the Musgrave, Macdonnell, and other ranges "are both in origin and in age essentially the same rock."

There are two views as to the nature and origin of the metamorphosed acid rocks of Central Australia: Brown,[*] Streich,[†] Basedow,[‡] Jack,[§] and others consider that while some are metamorphosed igneous rocks, others are clearly of sedimentary origin; Tate and Watt[||] find no evidence, in the region which they examined, for assigning a clastic origin to any of the gneisses and similar rocks, and criticise the views of Brown and others so far as these views apply to the geology of the Macdonnell Ranges.

It will be seen (p. 89, etc.) that no evidence in support of the first view has been found in the Warburton Area.

3. Clastic Rocks.

(a) *General Character and Distribution.*—So far as we have seen, these rocks occur only in small isolated patches in the metamorphic complex. Details of location will be given in the petrological section. That larger exposures do occur is indicated by the report[¶] of Mr. F. Hann's observations in "the neighbourhood of Mt. Squires":—

> "Here, from Mr. Hann's description, there is a large development of apparently vertical or highly inclined conglomerates seemingly similar to those of the Kurrawang series; the writer has seen pebbles from the 'Mt. Squires' conglomerate, and they have the same characteristics as those from the Kurrawang beds."

The Kurrawang conglomerates have (*loc. cit.*, p. 14) "since their deposition been subjected to considerable pressure and shearing," therefore, Hann's Mt. Squires conglomerates presumably also showed evidence of dynamic strain, and so cannot be representative of the Ordovician conglomerates (Townsend Range Series) described below.

(b) *Relation to other Rocks.*—Our observations were of too casual a nature to be worth detailing, but the impression we formed was that the beds in question were small patches "nipped-in" amongst the older members of the complex.

(c) *Petrology and Details of Field-Occurrence.*—Conglomerate-like rocks dipping north at high angles were found on the low country just south of Mt. Squires; about five and a half miles west of Mt. Squires; about nine miles east-north-east of Mt. Weir; and about four miles north-north-east of Mt. Eveline. Petrological examinations of specimens [$\frac{1}{1088}$] and [$\frac{1}{1083}$], from the first and second localities mentioned, show the rocks which, in hand specimens are dull greenish-black and usually clearly of fragmental origin, to be either greywackes or agglomerates. They contain lumps up to six inches in diameter, some rounded, some angular, of a very fine-grained dull green rock, and angular and sub-angular fragments an inch or two in diameter of a stratified quartzose rock (neither of these has been microscopically examined), also pebbles, sometimes well rounded, of porphyritic rock (see Appendix A, p. 174).

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[*] S.A. Parl. Paper No. 45, 1890, p. 2.
[†] Trans. Roy. Soc., S.A., Vol. XVI., p 82.
[‡] Trans. and Proc. & Rep. Roy. Soc., S.A., Vol. XXIX., p. 62.
[§] Geol. Surv. S.A., Bull. No. 5, p. 15.
[||] Rep. Horn Scientific Exped., Part iii., p. 40, etc.
[¶] G.S.W.A. Bull., No. 42, p. 15.

These agglomerates or greywackes show clear evidence in the field of having been sheared since their deposition (this, it will be seen, is confirmed by the microscope), the shear-planes striking east and west and dipping north at high angles.

The occurrence in the third and fourth localities appear to be of a similar character, but our notes regarding them are very scanty.

Sediments showing strong evidence of dynamic metamorphism were found near Barnard Rocks (Camp 55). The western end of a low hill two and a quarter miles west of the camp is made up of highly decomposed gneissic granite, but the greater part of the hill is a rock [$\frac{1}{1103}$] which has distinct, though coarse and rather irregular foliation-planes striking north-west and dipping north-east at about 70°, and is described as a metamorphic quartzite with granular andalusite. Again, the hill about one miles east of Camp 55 is composed of a dense black rock [$\frac{1}{1103}$] which is in contact with the granite [$\frac{1}{1104}$] (but whether unconformably overlying it or intruded by it could not be determined), and which was taken in the field to be a fine-grained basic gneiss. It proves, however, to be an agglomerate, probably graphitic, showing some evidence of shearing.

The mishap at Mt. Gosse prevented exploration to the south and east of Barnard Rocks, which would most likely have increased our knowledge of these sedimentary rocks.

At the contact between greenstone and acid rocks in the north-west corner of the Area, about one and three-quarter miles north-east of Camp 45 is a low hill, composed partly of the granular porphyry and partly of contorted schistose rocks,* in places green, in others white. The relation of these rocks to the neighbouring greenstone and porphyry was not determined, and their microscopic characters are contradictory, the green variety being possibly a sheared quartzite, while the white variety is "perhaps more probably derived from a porphyry or aplite than from a sediment." These rocks are, therefore, very doubtfully included with the metamorphosed sediments.

A dark-grey fine-grained rock [$\frac{1}{1060}$] found about five miles north-north-east of Camp 42 is described with some doubt as a "pseudoporphyritic granite arkose." Its field-relation to the surrounding granular porphyries is unknown, and it is tentatively included with the metamorphosed sediments.

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* Specimen [$\frac{1}{1078}$].

(d) *Correlation.*—The resemblance between the specimens collected by Mr. Hann near Mt. Squires and the Kurrawang conglomerates has already been noticed. The Kurrawang Series has been examined by C. G. Gibson [*] and C. S. Honman.[†] From Honman's latest account,[‡] it evidently bears much the same relation to the older rocks near Kalgoorlie that the beds just described do to the older metamorphic rocks.

We have not found reference to comparable rocks in reports on Central Australian geology except, perhaps, some of the Pre-Cambrian or Cambrian fragmental rocks described by Jack, and others.

B.—BASIC IGNEOUS ROCKS OF DOUBTFUL POSITION.

The rocks forming this group occur, some as well defined dykes, others as large masses, apparently intruded into the formations already described. As a rule they are remarkably fresh and show no signs of dynamic metamorphism, and so are doubly proved younger than the greenstones, granites, and metamorphosed clastic rocks. So far then our classification is natural and satisfactory.

The further separation of these basic igneous rocks into two subdivisions—Basic Plutonic Rocks and (younger) Basaltic Dolerites—is, however, of doubtful value, being supported only by a single observation (at Fort Welcome) on the correctness of which a good deal of doubt is thrown by petrological evidence. The correctness or otherwise of our field-work can be decided only by revisiting Fort Welcome, and it seems best to draw attention to the discrepancy between field and microscope-work by separating the finer-grained basaltic dolerites from the coarser gabbros and dolerites as a younger series while making it perfectly clear that this subdivision is founded on a single, possibly faulty, observation. If this one observation were ignored, it would be natural to regard all the Basic Igneous Rocks of Doubtful Position as more or less contemporaneous extrusions from the same magma.

1. **Coarsely crystalline basic plutonic and dyke Rocks:**

(a.) *Extent and general Character.*—Three large patches of gabbroid rock in the grey gneisses form Cavenagh and Blackstone Ranges and Morgan Hills. The boundaries of the patches are merely sketched in from their characteristic topography, which is described on p. 62, but their total area probably exceeds 160 square miles.

In the vicinity of the Cavenagh, Blackstone and Morgan Ranges, where these rocks were largely developed, there was a marked departure (from 5° to 20°) from the norcal reading of our compasses, which indicated the presence of magnetic minerals.

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[*] G.S.W.A. Bull., No. 42.
[†] G.S.W.A. Bullns., No. 56 and 66.
[‡] G.S.W.A. Bull., No. 66, pp. 12 and 35.

Dykes of the same rock, varying in width from a few feet to a hundred or even more, frequently occur in all parts of the area. Some, but by no means all, of the dykes noticed are indicated on the map.

(b.) *Relation to other Rocks.*—The larger patches of gabbroid rock are evidently batholiths intrusive into the gneissic rocks. They do not show any signs of dynamic metamorphism and must, therefore, be of later age than the rocks described previously. They are, however, tentatively regarded as older than the Basaltic Dolerites for reasons given below.

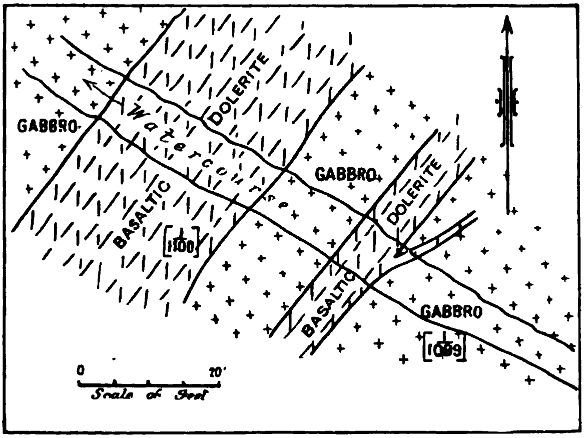
The doleritic dykes are clearly intrusive into the gneisses; they are identical with the gabbroid rocks in microstructure, and are probably contemporaneous with them.

(c.) *Petrology and Correlation.*—Full descriptions of these gabbros, norites, etc., and comparison with similar rocks from Western Australia and Central Australia will be found in Appendix A.

2. **Basaltic Dolerite:**

(a.) *Petrology and Details of Field-Occurrence.*—What appeared to us in the field to be clearly a dyke of fine-grained basaltic dolerite [$\frac{1}{1100}$] intruding the gabbro [$\frac{1}{1099}$] was seen in the water-course, a few yards below Fort Welcome Spring in Cavenagh Range (Fig. 42). Microscopic examination, however, shows that

Fig. 42.



Plan of Dykes in Gabbro at Fort Welcome, Cavenagh Range.

this "dyke" is considerably altered—so much so that "strictly speaking the rock should be classed amongst the Greenstones," whereas the rock which it intrudes is fresh. Our reason, in spite of this decrepancy between field and microscope work, for separating the Basaltic Dolerites from the more coarsely crystalline rocks has been mentioned above.

A basaltic dolerite [$\frac{1}{1088}$] to the south-west of Mt. Squires apparently intrudes metamorphosed sediments. Again [$\frac{1}{1109}$] from a dyke intruding gneissic granite in the hills about four miles west-south-west of Camp 57 (near Mt. Aloysius), is described as an ophitic dolerite, identical with the Sandstone and Meekatharra dolerites. Many other dykes (see Figs. 32, 36) occur in this neighbourhood, those on the slopes of Mt. Aloysius being traceable for long distances. Although specimens from Mt. Aloysius dykes were not obtained, there is little doubt that they closely resemble [$\frac{1}{1109}$].

At Table Hill, and near Ainslie Hill, volcanic flows, probably ordovician in age are intruded by dykes similar to those just described. On the denuded edge of the dyke at Table Hill rest the horizontal Wilkinson Range beds (*q.v.*).

It is probable also that to this division belongs an occurrence, about five miles north-east of Camp 45, marked "Basic Dyke" on Plate II., but not coloured accordingly, which requires further explanation.

The rock forming this dyke has weathered, in marked contrast to other basic dykes in the area, nearly everywhere to a white clay, in which, however, the relics of crystalline structure are still visible. The dyke, consequently, since it decomposes far more readily than the granular porphyries which it intrudes, is marked by a furrow, forming for part of its length the bed of a small watercourse, which runs south-west and affords easier travelling than the surrounding rough, stony ground.

This exceptional field-occurrence does not, however, warrant the fundamental difference in micro-structure between [$\frac{1}{1070}$] (supposedly from this dyke) and all other basic dykes in the area. [$\frac{1}{1070}$] is (Appendix A, p. 149) a coarse amphibolite—probably a dynamically metamorphosed gabbro, *i.e.*, one of the greenstone series, which (see above, p. 82) there is reason to believe is older than the porphyries which the dyke intrudes. Moreover, in the field, the unmetamorphosed character of the dyke is so strongly in contrast to the metamorphosed character of the intruded granular porphyries and to the micro-structure of [$\frac{1}{1070}$] that we must suppose [$\frac{1}{1070}$] to have been wrongly labelled in the field, and to come from the neighbouring greenstone area, which, indeed, yields boulders of a related "lustre-mottled" amphibolite.

(b) *Correlation.*—Specimen [$\frac{1}{1100}$] from Fort Welcome is, if our observations are correct, and despite its more altered state, of later age than the gabbro which it intrudes. A dyke of similar rock intrudes volcanic flows of probable ordovician age at Table Hill, and its denuded edge is overlain by sediments of supposed late Mesozoic or Tertiary age (see p. 100).

Some petrological resemblance to [$\frac{1}{1100}$] is the only excuse (and rather a doubtful one) for placing [$\frac{1}{1088}$] and [$\frac{1}{1100}$] here, and not with the basic plutonic and dyke rocks of the preceding section.

In fact, this section is dumping-ground for rocks of whose affinities we have almost no evidence.

Mr. Farquharson finds that these rocks recall dolerites from Meekatharra,[*] Cue,[†] Sandstone,[‡] and other places which it has previously been suggested [§] may be contemporaneous with the gabbroid rocks of the West Australian goldfields of which the counterparts have been described in the preceding section.

It has also been suggested [||] that, since the Oakover limestones are injected with similar dolerites, the dolerite of Meekatharra, etc., is even Post-Tertiary in age.

Comparisons based only on petrological detail are, of course, of little value, but it may be noted that the basaltic dolerites of the Warburton Area are apparently of later age than gabbros which also closely resemble the gabbros of the West Australian goldfields, and that these basaltic dolerites are apparently Post-Ordovician and Pre-Tertiary in age.

C. TOWNSEND RANGE SERIES.

(a) *General Character and Distribution.*—This series covers an area of about 275 square miles. Its rocks constitute Table Hill, Townsend, and Hocking Ranges and the bulk of the country lying between them and the Warburton porphyry dyke.

From below, upwards, the constituents of the series are conglomerates; volcanic flow-rocks; more or less calcareous grits; and quartzites. None of these show any signs of dynamic metamorphism.

The stratified members of the series and, in places, also the flow-rocks, strike east and west and dip south at about 20°.

(b) *Relation to other Rocks.*—The rocks under discussion were found outcropping in several places within a few chains of the metamorphosed rocks. In all such places the low dip and generally little-altered character of the Townsend Range Series contrasted so strongly with the structure of the metamorphosed rocks that no doubt could be felt that the former overlies the latter unconformably. It is, as a rule, the lower beds of the Townsend Range Series which are found outcropping near the metamorphosed rocks, but near Camp 41 large boulders of the Townsend Range quartzite mixed with boulders of greenstone (epidotised dolerite) are very common. Possibly, therefore, further search in this vicinity would show that the quartzites transgress over the lower members of the series, and lie directly on the greenstones, as one small quartzite patch on the left bank of Hughes Creek appears to do.

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[*] G.S.W.A. Bull., No. 68, p. 63.
[†] G.S.W.A. Bull., No. 57, p. 46.
[‡] G.S.W.A. Bull., No. 62, pp. 34–40.
[§] G.S.W.A. Bull., No. 68, p. 86.
[||] Id., p. 64.

As explained under the next caption, the inclusion of the Table Hill volcanics with this series is based on slender evidence. Assuming, however, for the moment the correctness of this correlation, we may note that, at Table Hill and near Ainslie Hill, these volcanic rocks are apparently intruded by a spheroidally weathered rock, too decomposed for profitable microscopic examination, but apparently a dyke of the basaltic dolerite (see p. 99). At Table Hill, also, the volcanic rocks are overlain unconformably by horizontal mudstones and current-bedded sandstones of the Wilkinson Range Series described later.

(c) *Petrology and Details of Field-Occurrence.*

(i) *Sedimentary Rocks.*—Exposures of the *lower sedimentary rocks* of this series were found at intervals along a belt extending from Cassidy Hill eastwards for about 14 miles. The regularity with which the various components of this band were met on different traverses testifies to the constancy of their strike.

The lowest bed [$\frac{1}{1080}$], [$\frac{1}{1120}$], strikes east and west and dips to the south at angles of 15° to 20°. It is dark-coloured, of fairly fresh appearance, and is clearly a "pudding-stone" or conglomerate made up of fragments—some rounded, some angular—of all sizes up to half an inch in diameter, of a variety of rocks, and also containing a good deal of calcite. The microscope shows that the fragments are glassy dolerite, quartz porphyry, microcrystalline quartz, decomposed greenstone, quartz and felspar crystals, and a micro-pegmatite.

This conglomerate thins out westward, being only a foot or two thick near Mt. Herbert, where it is interbedded with volcanic flows described later. Just south of Cassidy Hill it was not found, but instead [$\frac{1}{1042}$], a fine-grained gritty rock, and [$\frac{1}{1043}$], a coarser quartz-felspar grit with enclosed rock fragments, occur.

South of the conglomerate, and, since their strike and dip are the same, presumably overlying it conformably, are [$\frac{1}{1121}$] and [$\frac{1}{1079}$] which are fine-grained, dull green, gritty rocks evidently stratified, and showing a good deal of carbonate. These are best described as calcareous grits or impure limestone, and are also found in the vicinity of Ainslie Hill.

South of the band of calcareous grit only one outcrop of the lower beds of this series was noted. This is [$\frac{1}{1078}$] —a fine-grained dull green rock with a gritty appearance, which proves to be a fine-grained chloritic gritty greywacke—but much angular rubble of similar character was noted in various parts of Lilian Creek basin, which is therefore mapped as being composed of the Townsend Range Series.

The uppermost bed of the series is quartzite with a maximum thickness of between 300 and 400 feet, which, as a rather narrow band, can be traced almost continuously from the junction of Hughes and Elder Creeks to the east end of Townsend Range, and probably to Hocking Range (not visited by us). This quartzite has not been actually seen in contact with the rocks described above as belonging to the lower part of the same series. It is assumed to overlie them conformably because its strike and dip are parallel to theirs, and because, in the absence of distinct evidence, it seems unwarrantable to constitute them another series without counterpart in Central Australian geology.

The precipitous north face of Townsend Range (Fig. 8), the lower cliffs south-west of Hughes Creek, and probably those of Hocking Range, are escarpments in the quartzite; the gradual southern slopes of these hills are dip-slopes.

The quartzite [$\frac{1}{1146}$] is buff-coloured in mass and contains small, inconstant seams of water-worn quartz pebbles at irregular intervals. Where crossed by joints (by which the rock is split into great blocks) these pebbles are very cleanly sliced.

(ii) *Volcanic Rocks*.—The field-relation of these to the lower sedimentary beds of the series is fairly well seen near Mt. Herbert, and is diagrammatically illustrated in Fig. 43. In actual fact, of course, merely the edges of the successive beds were observed, together with an occasional dip. The inference, made in the field, that we have here a succession of lava flows with an interbedded seam of conglomerate, is, however, thoroughly supported by petrological work and by the occurrence in the conglomerates described above (p. 100) of pebbles of similar volcanic rocks. It is thus inferred that volcanic eruptions were taking place near by while the conglomerate was being deposited.

The volcanic rocks are fine-grained, dark-green, and have numerous small rounded patches of carbonate, sometimes containing yellowish-green epidote, which have a superficial resemblance to the irregular blebs of quartz found in the neighbouring greenstones (see p. 83). In fact, the only characteristic which distinguishes these rocks in the field from the greenstones is the absence of shearing. Microscopic examination of [$\frac{1}{1122}$], [$\frac{1}{1124}$], and [$\frac{1}{1123}$] proves that they are fine-grained, vesicular doleritic or basaltic lavas, in which epidote and chlorite are abundantly developed.

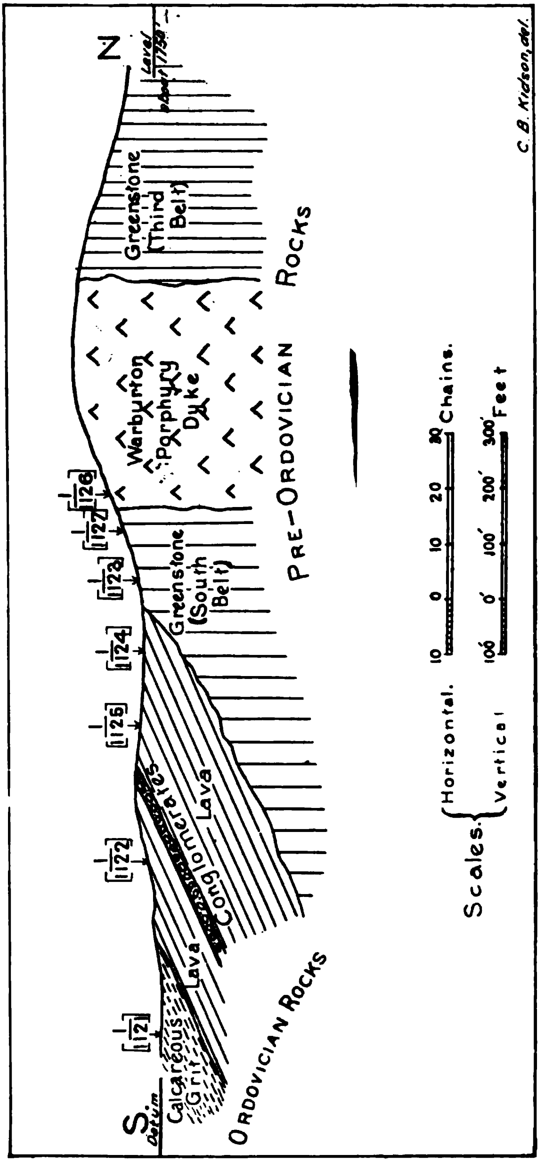
Six miles farther east [$\frac{1}{1081}$], a very similar rock, underlying conglomerate like [$\frac{1}{1080}$], is assigned to the same series.

The same belt was found to the west, near Hughes Creek, as the descriptions of [$\frac{1}{1076}$] and [$\frac{1}{1077}$] testify. In this locality the quartzite overlies the volcanics directly.

The *Volcanic Rocks of Table Hill* are doubtfully assigned to the same horizon as those just described.

Both were originally basalts or dolerites, but this, of course, is no proof of their contemporaneity. Moreover, the rocks near Mt. Herbert, etc., differ from those of Table Hill in their alteration—for, while the former are dull green in colour owing to con-

Fig. 43.



Section through Mt. Herbert, to show the relation between Ordovician and older rocks.

siderable development of chlorite, epidote, and zoisite, the latter do not contain these minerals but are brown from abundance of iron oxide. Again, the vesicles of the rocks near Mt. Herbert are filled with epidote, calcite, or both, while those of the Table Hill rocks are filled with quartz. Even, then, if these two sets of lavas flowed out at the same time, the differences in secondary alteration show that they have since been very differently situated with regard to the various agents of alteration.

As to field-evidence—the Table Hill rocks occur, as far as we know, in a patch separated from other members of the Townsend Range Series by sand-hill country, and (if they are coeval with the Mt. Herbert volcanics) their position some eight miles south of the south-dipping and overlying quartzites necessitates the introduction of a syncline (see Section A-B, on Plate II.), or else a fault, between Table Hill and Townsend Range, for which there is no evidence.

In spite of these difficulties, however, there scarcely seems warrant for constituting the Table Hill rocks a separate series. Descriptions of specimens [$\frac{1}{1147}$] to [$\frac{1}{1156}$] will be found in Appendix A.

(d) *Correlation.*—No fossils having been found in the sedimentary rocks of the Townsend Range Series, their age is not directly determinable. However, we propose to show, as briefly as possible, that there is fairly good proof of their ordovician age —if we correlate them with similar rocks to the east. Lithologically similar rocks from the west have been, it is true, classed as devonian; but evidence in support of this classification is lacking.

On the "Map of the Route travelled by the Elder Exploring Expedition,"* Streich showed a band of "Palæozoic (Devonian)" rocks extending from the south-west end of Everard Range to Townsend Range. He did not himself visit the Warburton Range, but from specimens brought by others mapped it (with some hesitation), and also two other bands to the north-west, as devonian. The reputed Warburton specimens probably came from the escarpment south-east of Hughes Creek.

From his description† it is evident that this "Devonian" band is constant in character throughout its length, its predominant bed being quartzite like that of Townsend Range.

Near Lake Macdonald the staple formation observed by Tietkens ‡ was "Devonian" quartzite.

The idea that this widely distributed formation was of devonian age appears to have originated in H. Y. L. Brown's "Report on Journey from Warrina to Musgrave Ranges,"§ in which he compares the quartzites south-east of Everard Range to the

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* Trans. Roy. Soc., S.A., Vol. xvi.
† Loc. cit., pp. 77, 82.
‡ S.A. Parl. Paper, No. 111. 1889.
§ S.A. Parl. Paper, No. 45, 1890.

"tenthills of Port Augusta and the flat table ranges on the Hugh River south of the Macdonnell Ranges." The tenthill formation he had previously [*] correlated with the devonian beds of New South Wales.

Tate and Watt, however, [†] found numerous ordovician fossils in quartzites and limestones in various places south of the Macdonnell Ranges, and considered that the quartzites found by Tietkens near Lake Macdonald were also ordovician.

Brown [‡] later acknowledged the probable ordovician age of the quartzites, etc., near Arcoeillinna, at Chambers Bluff, Mt. Chandler, etc., and Jack, [§] by speaking of the "ordovician" rocks "mapped by the late Victor Streich," makes it clear that the latter's "Devonian" right through to the Warburton Area may, with tolerable certainty, be regarded as ordovician.

It must be noted, however, that whereas in the ordovician rocks south of the Macdonnells there is a marked absence of volcanics, [||] such rocks are well represented in the basal part of the Townsend Range Series. This lends colour to the objection (noted in describing the petrology, etc., of the quartzite, p. 101) to including these lower beds with the Townsend Range quartzites as one conformable series.

Turning now to the age of similar rocks in Western Australia:—

The quartzites of Townsend Range bear a striking resemblance to those which one of us (H. W. B. T.) has mapped over very extensive areas from Lake Wells, 200 miles west-south-west of the Warburton Range, to Kimberley. [¶]

The distribution, character, and age of these rocks in the Kimberley were examined by Hardman,[**] Woodward, [††] and Dr. R. Logan Jack, [‡‡] who agree in calling them devonian.

On examining the reports of these geologists it seems to us that, although undoubtedly fossils of a devonian aspect have been found in Kimberley, they were not obtained in beds belonging to the series which covers such a large area between Lake Wells and Albert Edward Range, in Kimberley, but came from limestones which it is difficult to separate, except by their fossils, from the carboniferous strata.

We hope to discuss this matter more fully at an early date in a paper to be read before the Royal Society of Western Australia.

It appears to us that the evidence from Central Australian geology favouring the assigning of an ordovician age to the Townsend Range Series outweighs that for a devonian age, which Kimberley geology may be thought to furnish.

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[*] S.A. Parl. Paper, No. 35, p. 10, 1884.

[†] Report Horn Exped., Part III., p 46, *et seq.*, S.A.

[‡] Rep. on Geol. Expl. in West and North-West of S.A. (Parl. Paper, No. 71, p. 9, 1905.)

[§] Geol. Surv., S.A., Bull No. 5, p. 23

[||] Rep. Horn Exped., Part III., pp. 53–4.

[¶] G.S.W.A. Bull No. 39, and the forthcoming Bull. No. 77.

[**] W.A. Parl. Paper, No. 34 (1885).

[††] "Report on the Goldfields of the Kimberley District," Perth, 1891.

[‡‡] G.S.W.A. Bull., No. 25.

D. Superficial Deposits.

Superficial deposits in the form of talus-slopes, sand, loam, travertine, chalcedony, etc., cover a considerable portion of the Warburton Area, but are probably of inconsiderable depth, and are not indicated on the map except by notes. They are similar to those in the Dunge's Hill-Townsend Range Section, and need not be described here. Perhaps the most noteworthy travertine deposits are those of the Lilian Creek Basin, especially near the Depot Camp, while superficial deposits of mixed chalcedony and travertine were particularly prominent to the east and north-east of Mt. Weir.

IV. DUNGE'S HILL—TOWNSEND RANGE SECTION.

Only two formations are found over this stretch of 250 miles—horizontally bedded sediments containing evidence of ice-action, and various superficial deposits.

A. Wilkinson Range Series.

(a) *General Character and Distribution.*—The rocks under consideration are well exposed in the Wilkinson Range near Lily Rock-Hole, and are, for convenience, called the Wilkinson Range Series. They consist of sandstones, sandy claystones, claystones, and boulder-beds, and everywhere appear to be horizontally bedded.

The series is exposed intermittently throughout the Section, forming isolated table-tops and lines of breakaways, separated by expanses masked with superficial deposits. The latter are probably of no great depth, and have been omitted in mapping, so that, on the map, the Wilkinson Range Series covers more country than it appears to do in the field.

(b) *Relation to other Rocks.*—In the north-west corner of the Warburton Area, near Camp 44, the rocks under discussion lie on an eroded granite surface, as they also do at Dunge's Hill. Between Dunge's Hill and Point Salvation (in the next "section") they similarly overlie both granite and greenstone. They unconformably overlie the volcanic rocks of Table Hill (p. 100), and may reasonably be supposed also to be unconformable to the quartzites of Townsend Range.

(c) *Petrology and Details of Field-Occurrence.*

(i.) *Sandstones.*—Apparently the bulk of the Wilkinson Range Series is made up of sandy beds (Figs. 14, 44, etc.). These are light-yellow, brown, or white in colour, medium coarse in grain, and, where not secondarily "laterised," are soft. They usually contain a noticeable amount of clay, generally in specks, probably kaolinised felspars. By increase in the proportion of clay the rocks become sandy claystones.

Fig. 44.

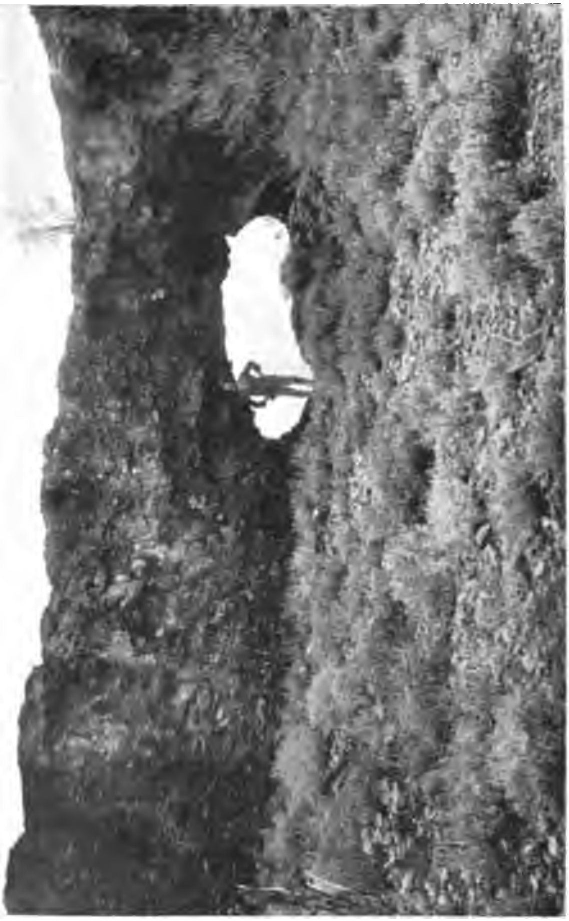


Photo: E. de C. Clarke. Neg. 1472.

WILKINSON RANGE BEDS.—Near soak in Millar Breakaway. Roof of arch formed of resistant laterized surface-layer.

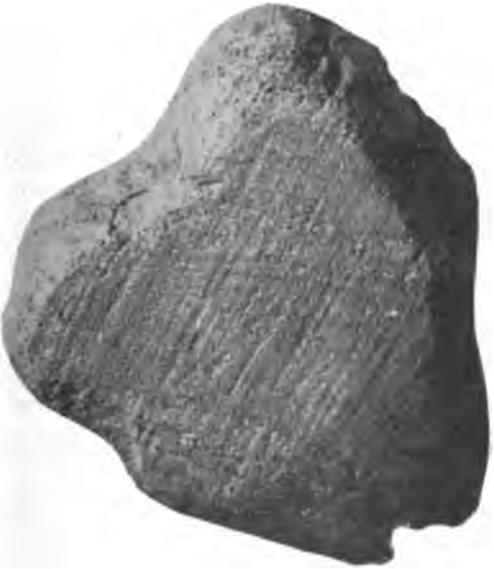
The sandy rocks often show strong current-bedding and sometimes contain isolated pebbles and boulders up to six inches in diameter, showing the same peculiarities as those composing the boulder-beds.

(ii.) *Claystones* occur less frequently than sandstones and sandy claystones. They are usually white or yellow in colour and compact, though soft. Where not "laterized" they are particularly liable to deflation, as described in Chap. II., p. 57.

(iii.) *Boulder-Beds.*—In many places near the foot of breakaways between Wilkinson Range and Axe Hill, a distance by our route of about 200 miles, are strewn numbers of rock-fragments, varying in size from mere pebbles to boulders weighing several hundredweight. Along the west side of the Point Saunders breakaways these boulders are nearly all derived from a definite boulder-bed about 15 feet thick, which is the lowest visible member of the Series, and is covered by 100 feet or more of the finer sediments already described, in which an occasional boulder or pebble can be found. A short distance north of Camp 33 (near Fetherstonhaugh Hill) a similar boulder-bed can be seen. Again, in Wilkinson Range, near Lily Rock-Hole, the fact that boulders are not found above a certain height on the talus-slopes of the breakaways indicates that here also there is a definite boulder-bed.

Since the sandstones, etc., which conformably overlie the boulder-beds are everywhere horizontal, and since the country between Wilkinson Range and Fetherstonhaugh Hill is practically level (according to heights determined by aneroid) the boulder-beds must form, if not a continuous bed, at any rate a definite horizon for this distance.

Fig. 45.



Phoeo. R. H. Irwin. Neg. 1493.

GLACIATED GNEISS BOULDER.—From Wilkinson Range Beds, about one mile S.W. of Lily Rock-Hole. Foliation-planes (dimly visible) make an angle of about 70° with the scratches.

The majority of the medium-sized boulders and pebbles examined agree in shape, being rounded and smoothed as by water-action, but with one conspicuously flattened side which, in some cases, is traversed by groovings independent of the rock-structure (Fig. 45.) Occasionally facetted boulders were found (Fig. 46).

Fig. 46.

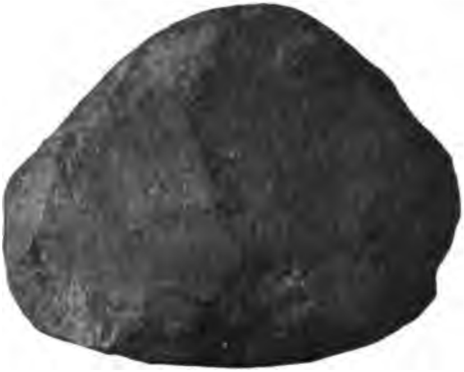


Photo: R. H. Irwin. Neg. 1494.

FACETTED QUARTZITE BOULDER.—From Wilkinson Range Beds, about one mile S.W. of Lily Rock-Hole.

The larger fragments, weighing two hundredweight or more, are well rounded, but we had not time to ascertain whether the flattened side which, after the weathering-out of the boulders, seems generally to settle undermost, was present.

The most obvious explanation* for boulders of such shapes is that they are water-worn rock-fragments which became embedded in the foot of a glacier, the flat faces being produced by grinding against the glacier-bed.

A boulder-bed of such constant thickness and conformity with overlying shallow-water sediments could not be a sub-aerial morainic deposit, but must have been formed of debris dropped in shallow water by icebergs.

Many different rock-types were found among the boulders of the Wilkinson Range. These have not been examined microscopically, but the following list of hand-specimens, in which the most abundant types are described first, the rarest last, may be of interest:—

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* The great number of such boulders (quite apart from the exposure of a defined boulder-bed on the west side of Point Saunders Breakaways) precludes the idea that they are blacks' grinding-stones.

Coarse gneissic granite like some of the types from the Warburton Area, intermediate between the "pink" and "grey" rocks.

Granular crystalline pink granite like some of the "pink rocks" of the Warburton Area.

Granular crystalline rocks resembling coarser varieties of the pink granular porphyries from the Warburton Area.

Gneissic, pink-and-grey, biotite granite.

Gneissic rock resembling [$\frac{1}{1133}$].

Fine-grained grey granular granite with coarse microcline-pegmatite areas.

Dull pink-grey sericitic gneiss like "holz-gneiss."

Pink aplite.

White and blue quartz.

Finely foliated and sheared dark-grey biotite gneiss.

Quartzite like that of Townsend Range.

Apparently unsheared quartz-porphyry like many dyke-porphyries of Warburton Area.

Some of the coarse granitic rocks resemble the pegmatite facies of the granites near Kookynie, but otherwise rocks resembling most of this assemblage in megascopic characters have not yet been described from any part of Western Australia except the Warburton Area.

Boulders of granite were found only in Wilkinson Range. Elsewhere the largest boulders were quartzite of the Townsend Range type, the smaller boulders were quartzite and quartz, and, at Point Saunders, in addition to these, a highly siliceous rock, apparently a completely silicified limestone.

As noted above (p. 104), quartzites of the Townsend Range type occur over wide areas north-west, north, and north-east of the Dunge's Hill-Townsend Range Section; they are unknown to the south.

Our failure to find a variety of rock-types in any of the boulder-bed exposures except that at Wilkinson Range may, of course, be due to hurriedness of observation. If, however, the variety is really absent from the boulder-beds north of Wilkinson Range, we must conclude that the bergs which dropped such a rich assortment of debris over the site of Wilkinson Range originated from different glaciers, which probably lay on an area of crystalline rocks west of the Warburtons, to the bergs responsible for the boulder-beds further north.

In any case it is evident that, at the time of formation of these beds, glaciers vigorous enough to descend to sea-level occupied country as near the tropics as lat. 26° 30′.

(d.) *Correlation.*—Fossils have not been found in the Wilkinson Range Series, and, in attempting to correlate it with previously described formations containing evidence of glacial action, we meet with little satisfaction.

The permo-carboniferous Lyons Conglomerate[*] presents apparently indisputable evidence both of its age and its glacial origin. There is nothing except their glacial origin to justify our correlating the boulder-beds of the Wilkinson Range Series with this conglomerate.

The "low hills" frequently passed by the Elder Exploring Expedition south of our route are probably of the same character as the breakaways along the Dunge's Hill-Townsend Range Section. These hills are composed of sandstone, clay, etc., in which beds of waterworn quartz pebbles occur frequently. Streich [†] classified them as doubtfully mesozoic, relying on their "lithological and stratigraphical features [which] are in agreement with those of the typical area in Australia. Moreover, they resemble the Cretaceous deposits met with in the early part of our journey, which have been proved to be of that age by means of fossils."

Again, according to Tate and Watt, [‡] the argillaceous strata round Lake Eyre are proved palæontologically to be upper cretaceous. These argillaceous strata are capped by a hard flinty quartzite or chalcedonised sandstone varying up to 50 feet in thickness, which forms the topmost bed of the table-land country, and is generally called the Desert Sandstone, to which they assign a supra-cretaceous age.

Amongst many other localities in which the cretaceous strata are mentioned as occurring is "the Finke River from Henbury to Crown Point, which flows approximately along the junction of the Cretaceous arenaceous beds and the impervious ordovician limestones," and (*loc. cit.*, p. 72) this locality is described as more or less characteristic of the Tertiary deposits.

However, later investigations by Spencer and Byrne [§] summarised by the Glacial Research Committee of the Australasian Association for the Advancement of Science showed that at Yellow Cliff, on the Finke River, a pebble-layer about three feet thick occurs, the pebbles of which show undoubted evidence of glacial action. After discussion, the opinion is expressed that the evidence, "slender as it is, is in favour of a permo-carboniferous age for these traces of glaciation in Central Australia."

Another possibility was suggested by H. Y. L. Brown, [‖] who, in the course of an extended geological reconnaissance, noted that "on the stony downs, gravelly plains and tablelands, boulders and blocks of rock are frequently seen resting on cretaceous shale and silt. These consist of quartzite, clay, siliceous slate, felspar, porphyry, sandstone and quartz, etc. One solid block measured 5ft.

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[*] "Relics of the Permo-Carboniferous Ice Age in Western Australia."—By A. Gibb Maitland, F.G.S.—Jour. Nat. Hist. & Sc. Soc. of W.A., Vol. IV.

[†] Trans. Roy. Soc., S.A., XVI., pp. 91–2.

[‡] Rep. Horn Exped., Part III., p. 62, *et seq.*

[§] Aust. Assoc. Adv. Sc., Sydney, 1898. "Report on the Occurrence of Glacial Boulders at Yellow Cliff . . . . . . Central Australia."

[‖] Rep. Geol. Exp. in W. and N.W. of S.A., S.A. Parl. Paper, No. 71, 1905, p. 5.

by 4ft. by 1ft. 8in., and larger but shattered blocks occur; these, without doubt, have been transported to their present position by ice-action, which seems to have, at some time since the Mesozoic period, been in operation all over the region."

Again (p. 6), he noted the occurrence of a granite erratic "suspended in shale" at a depth of 3,100 feet in the Arkeeta claypan bore. This he considered evidence of ice-action at the time the shale was deposited (the rocks shown at the surface on the map are post-tertiary).

Jack* describes upper cretaceous rocks from the north flanks of the Everard Range and elsewhere in the western portion of the area with which he deals. He also (pp. 42-4) discusses the probability of drift-ice in the lower cretaceous sea to account for the wide distribution of erratics, as already noted by Brown. He favours this explanation of the erratics rather than the view that they are boulders of the cambrian till, redistributed by torrential streams in geologically recent times.

It appears to us that the little evidence we have favours the assigning of a late mesozoic or tertiary age to the Wilkinson Range Series.

B. SUPERFICIAL DEPOSITS.

The following account is applicable to the superficial deposits seen in all parts of the route, and not merely to those of the Section now under discussion.

The Superficial Deposits may be divided into those formed by chemical and those formed by mechanical action.

1. Formed by Chemical Action.

(a) *Laterite.*—Good examples of the formation of laterite by the alteration of rock *in situ* were noted in the soft beds of the Wilkinson Range Series. Solution and re-deposition both of silica and of iron-oxide go on together, the silica or iron-oxide predominating in any particular place, according to local conditions. Reference is made in the physiographic chapter (p. 55) to the character of the hardened cap so formed, to its influence on the formation and undercutting of breakaways, and to its probable identity with the "Desert Sandstone."

(b) *Travertine and Chalcedony.*—These were noted chiefly in those parts of the Warburton Area which are underlain by greenstones and by sedimentary rocks formed of their waste. Thin deposits in which chalcedony predominates over travertine are commoner than pure deposits of either alone.

(c) *Kopai.*—Travellers (*e.g.*, Carnegie†) by this name refer to soft deposits, largely of gypsum, found near salt lakes. They are formed by the ascent by capillarity through the sand of water rich in various salts which has been concentrated by evaporation in the "lake" after heavy rainfall. On reaching the surface the water is evaporated and the salts are deposited—in some cases in pulverulent form (in which case the deposit is quickly removed by the wind), in other cases as a harder encrustation, perhaps protecting the powdery form below.

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* Geol. Surv., S.A., Bull. No. 5. p. 24.

† "Spinifex and Sand," p. 43.

An encrustation of this character from the shores of Lake Yeo (near which feature borax claims are said to have been pegged), near Camp 17, was examined in the Geological Survey Laboratory. Mr. Simpson reports concerning this:—

Lab. No. 10084. Soft Portion: mainly gypsum with kaolin and quartz grains. Boron, nil.
Hard Portion: gypsum with a little travertine. Boron, nil.

2. **Formed by Mechanical Action.**—The boulders, pebbles, sand and finer loamy material forming talus-slopes, sand-hills and plains are the representatives of this class of superficial deposit. Further description is unnecessary, the features which they constitute being described in Chapter II.

V. LAVERTON—DUNGE'S HILL SECTION.

The bulk of the country passed over in this portion of the route consists of granite, concealed in many parts by superficial deposits. In the granite are two small belts of greenstone. Horizontally bedded sediments are found overlying granite and greenstone as far west as Point Salvation.

A. Metamorphosed and Igneous Rocks.

1. Greenstones.

(a) *General Character and Distribution.*—A belt of greenstone about one and a quarter miles wide was crossed at Mt. Sefton, about 60 miles east-north-east of Laverton. No trace of it was found five miles to the north-west on the return route, but it may be hidden by superficial deposits. It is approximately on the line of strike of the Cosmo-Newberry Belt lying 30 miles to the north-west which was described by Gibson.* Nothing is known as to its southern extension.

A second belt (Point Salvation Belt) lies east of Point Salvation and is, perhaps, five miles wide. From its position it may be continuous with Gibson's Mt. Shenton Belt 15 miles to the north-west.†

(b) *Relation to other Rocks.*—On the eastern edge of the Mt. Sefton Belt the granite is fine grained and porphyry-like, implying that it is later than and intrusive into the greenstone. This is the only indication noticed as to the relative ages of granite and greenstone. Greenstone is unconformably overlain by the Wilkinson Range Series at Tobin Hill.

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* G.S.W.A. Bull. No. 24, pp. 67-71.
† *Loc. cit.*, pp. 71-73.

(c) *Petrology.*—The Mt. Sefton greenstones are dark green in colour, showing considerable range in texture—from fine-grained sheared rocks to coarse rocks showing little or no shearing. In hand-specimens small needles and crystals of hornblende are the only clearly recognisable mineral. [$\frac{1}{1024}$] and [$\frac{1}{1025}$] fine and coarse-grained specimens respectively, are described in Appendix A. Both are sheared epidiorites, probably closely related.

The western half of Point Salvation Belt consists of very strongly sheared greenstones (*e.g.*, [$\frac{1}{1027}$]), the eastern of a more massive rock (*e.g.* [$\frac{1}{1028}$], [$\frac{1}{1030}$]) which, although its minute structure is too much obscured by weathering to justify detailed description, is of igneous origin, and is probably an amphibolite. The coarse joints of this rock strike south-south-east and dip north-north-east very steeply. A highly ferruginous jasper bar [$\frac{1}{1029}$] is developed in it at the west end of Tobin Hill.

(d.) *Economic Possibilities.*—These are briefly touched on in the next chapter.

2. **Granite:**

(a.) *Extent and General Character.*—As already stated, granite forms the bulk of the country under discussion. The relation of this rock to the greenstones and Wilkinson Range Series has been already indicated.

(b.) *Petrology.*—In the field the granites of this section are clearly but not very strongly sheared. They outcrop as rounded knobs like Point Uhr, or as breakaways like Point Kidman. Quartz veins are not abundant in the granite and are probably quite barren. The most conspicuous quartz vein is that forming the "blow" near Point Salvation soak.

Two specimens of granite [$\frac{1}{1035}$] and [$\frac{1}{1036}$] have been examined by Mr. Farquharson. That from Point Uhr is a medium-grained light-coloured rock, which proves to be a biotite-microcline granite. The coarse-grained darker rock from Point Salvation is a biotite-hornblende granite. Mr. Farquharson considers that the granite masses represented by these specimens are not genetically connected, but there is no field-evidence to offer on the subject.

B. WILKINSON RANGE SERIES.

Rocks of this series were noticed at Point Salvation and at Tobin Hill. At Point Salvation small exposures, both of claystone and of sandstone, were noticed, unconformably overlying granite.

At Tobin Hill the series is represented by rather coarse grits, which unconformably overlie the greenstones and contain well rounded quartz boulders up to 1ft. 3in. in diameter.

C. SUPERFICIAL DEPOSITS.

These are of the types described in the preceding section.

CHAPTER IV.

RESOURCES.

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I. MINERAL.

A. MINERALS OTHER THAN GOLD.

1. **Copper, etc.**—The granite and gneiss which compose a large part of the Warburton Area have been shown (Chapter III. and Appendix A) to be close counterparts of rocks forming the backbone of the Musgrave, Everard, and MacDonnell Ranges in South Australia, in which there has been a good deal of almost fruitless search for various minerals. From what we saw, prospects in the corresponding rocks of the Warburton Area are no more encouraging.

Mr. F. Hann took samples from a copper "lode" two or three miles west of Mt. Waugh, which yielded more than 12 per cent. of copper, besides 1oz. 5dwt. of silver and a trace of gold. Mr. Hann considers the deposit too small to be of value, but this locality and all the porphyry belts are well worth further examination for similar lodes and for large low-grade deposits.

2. **Deposits of Borax** are said to have been located on or near Lake Yeo. Specimens collected by us from the lake yield no trace of this mineral (see p. 112).

It may be of interest to state briefly the conditions under which it is thought that borax has been deposited, and to consider whether any of these conditions obtain in the neighbourhood of Lake Yeo.

According to Clarke* three hypotheses have been proposed for the origin of boric acid and saline borates. First, they may have been derived from the leaching of rocks containing boro-silicates, such as tourmaline. Second, they may be of volcanic origin. Third, they may have been deposited from sea-water in shallow parts of the sea isolated from the main ocean. The first mode of derivation has not, he continues, been directly tested anywhere; the volcanic theory seems to fit a number of localities, though its validity for others has been doubted; the marine theory undoubtedly applies to such occurrences as those of Stassfurt, but merely removes the difficulty a step, since we can only guess as to how the borates came to be in the sea-water. He inclines to the view that volcanic action is ultimately responsible for borate deposits.

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* F. W. Clarke, "Data of Geochemistry," 3rd Edition, p. 251, etc.

Borax deposits have not yet been found in Western Australia though, if borates exist in the rocks, climatic conditions are suitable for their accumulation in the many "lake" basins.

In the light of recognised theories of the origin of borax-deposits, and with our very scanty knowledge of the region in question, there seems no hope of the future discovery of such deposits near Lake Yeo, for neither is there evidence for the existence of boro-silicate-bearing rocks nor of former volcanic activity in the area draining into the lake, nor do the sedimentary rocks of that area show any evidence of having accumulated in a sea isolated from the main ocean.

B.—Gold.

It is, however, to the gold-bearing possibilities of the Warburton Area that popular attention has been directed.*

The geology of gold-mining centres in Western Australia leads us to expect payable deposits almost solely in or near greenstone belts. Low-grade deposits are indeed known to occur in sedimentary rocks in this State, *e.g.*, in the Nullagine conglomerates† and at Mt. Singleton. This suggests enquiry as to the possibility of gold, both in the metamorphosed sediments (see pp. 94-96) and in the lower beds of the Townsend Range Series (see pp. 99-105). However. deposits of this character would be almost certainly low grade and quite unworkable for many years to come in such a remote region as the Warburtons, so we may confine our attention to the possibilities of the greenstones.

In Chapter III. it is shown that besides the patch of greenstone country divided into four belts (see Fig. 38) by great porphyry dykes in the Warburton Area, small belts were found at Mt. Sefton and at Point Salvation (Plate I.)

The possibilities of these greenstone areas as gold-bearing belts may be summed up as follows:—

1. Mt. Sefton and Point Salvation—

Near the east edge of the Mt. Sefton Belt, evidence of intrusive porphyry dykes was seen, but no quartz veins, except a few small lenses were noted. The greenstones are indeed somewhat sheared in places and possibly values may be found, but this belt does not offer much inducement to the prospector.

The ground in the middle part of the Point Salvation Belt, and near Tobin Hill, is strewn with quartz rubble, but vein-outcrops are hidden by over-burden. This belt, which has apparently been traversed by at least one party of prospectors, is more promising than Mt. Sefton.

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* See for example the account of one of Mr. Hann's expeditions in the *West Australian*, March 1, 1907.

† G.S.W.A. Bull. No. 20, p. 18, *et seq.*

The soak at Point Salvation should supply water for a small party in any ordinary season.

2. Greenstone Belts of Warburton Area—

Several samples, collected in the Warburton Area by Mr. Hann, were assayed in the Geological Survey Laboratory some years ago, but none yielded more than a few dwt. of gold per ton.

We are doubtful (as explained on p. 82) regarding the correctness of the mapping of the "North Belt" of greenstone (see Fig. 38 and Plate II.), but subsequent parties will at any rate gain from our map a fairly definite idea as to the most probable position of the greenstone country which they may desire to prospect.

The eastern end of the North Belt, between Mts. Waugh and Eveline, shows few signs of quartz veins. Wherever else this belt was examined, quartz was abundant, occurring usually as rubble and boulders, but quartz lenses and veins were frequently noticed, running parallel to the foliation of the rocks, *i.e.*, west-north-west and east-south-east. A piece of quartz from a vein apparently passing out of porphyry into greenstone, just north of Johnson Creek, yielded (Lab. No. 10056) a trace of gold. Larger veins exist near the location of specimen [$\frac{1}{1073}$]. A piece of quartz from one of these yielded (Lab. No. 10057) a trace of gold. There is also much quartz strewn over the ground near Camp 45. An assay of a piece of this quartz gave (Lab. No. 10058) 5 grains per ton. It is probable that large veins are hidden by the over-burden in this part. A quarter of a mile west of Camp 45, a quartz blow probably marks the contact of greenstone and porphyry. Prospecting in the western portion of the North Belt is certainly warranted.

Although quartz veins, having the same strike as those of the North Belt, were noted in the second belt of greenstone, the bulk of the country seen by us was not "likely." However, the unexamined patch of 70 square miles between Camps 42 and 67, mapped as greenstone, deserves attention, especially as signs of mineralization were noticed in the greenstones just north of Camp 42. A specimen of quartz (Lab. No. 10054) collected 50 chains North of Camp 42, yielded 10 grains of gold per ton, and another (Lab. No. 10055) 70 chains further north, gave 8 grains per ton.

The Third and Fourth Belts appear to offer fewer chances to the prospector than those to the north, but the chloritic slates near Warburton Creek and Frank Scott Hill form "kindly" conntry, and may be found in greater strength north-west and south-east of the parts examined. The backbone of Ainslie Hill is a strong east-and-west vein of manganese-bearing quartz, which looks unpromising, but the country between Hughes Creek and Warburton Range should be examined.

Summarising.—There is no doubt that the Warburton greenstones are similar to those found in the Western Australian Goldfields. It does not follow, though, that rich gold deposits will be found near the Warburtons. It is only necessary to call to mind the big areas of greenstone country in this State, which up to the present have yielded little or no gold, to convince ourselves of this fact. Again, no false hopes must be raised by the abundance and size of the porphyry dykes. The Warburton porphyries may have a beneficial effect on the greenstones, but at present this is "not proven."

On the other hand, the fact that this expedition has not brought back rich gold "specimens" is no great matter. Our primary object was the mapping of the waters and main geological features so that future prospecting parties would know where water is to be found and where prospecting is warranted.

Our account of the route followed makes it clear that except for small parties the journey to Warburton Range cannot be made safely, even with camels, without the sinking of at least three wells at intervals of about 100 miles, in the "desert." Also, for the proper prospecting of the Warburtons, a well should be sunk at about the junction of Warburton and Elder Creeks. From the account of the greenstone belts just given, it is evident that the area of possibly auriferous country so far discovered is small, but that it probably extends, particularly to the north-west, farther than we were able to go.

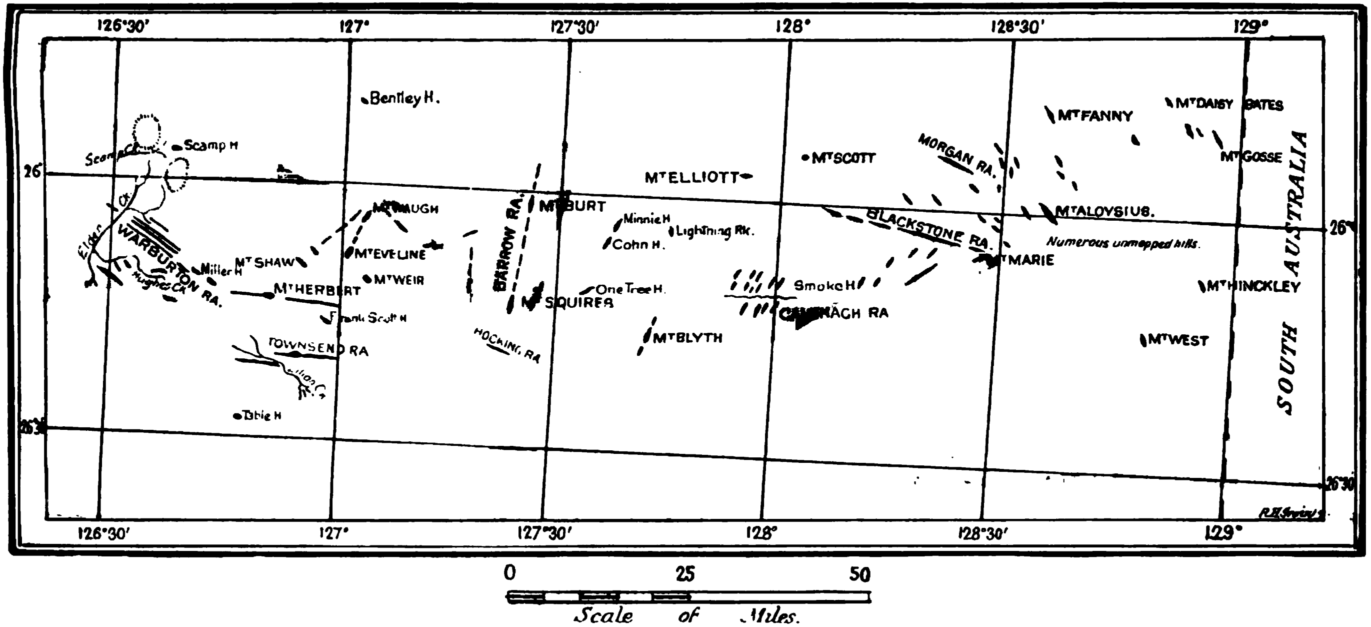
II. PASTORAL.

Between Laverton and the Townsend Range there are a few small areas, generally in the vicinity of breakaways, suitable for the grazing of stock, but none seen by us were of sufficient size to warrant their being taken up for pastoral purposes. They form oases in a desert area, and as such would be of value if a stock route were opened to the Warburton Area or to South Australia.

Between the west end of the Warburton Range and the South Australian border there are three patches (see Fig. 47) that could, in good seasons, be as heavily stocked as the best stations of the Gascoyne and Murchison. We estimate that north of the Townsend Range and eastward of Elder Creek there is a block of approximately 640,000 acres, around the Barrow Range about 120,000 acres, and between the Cavenagh and Blackstone ranges another 120,000 acres, suitable for grazing purposes. In each of these blocks there is a lot of waste country unsuitable for stock, but the proportion of barren country is no greater there than in many of the stations in the settled districts.

The country, however, appears to be subject to long periods of drought. In places about 80 per cent. of the mulga was dead; and it was quite a common thing to see 40 to 60 per cent. without

Fig. 25.



Plan showing approximate area of Pastoral Country.

a sign of life. At first, we were inclined to attribute the large amount of dead mulga to bush fires, but usually there was no sign of charring on the bark of the trees. We had a copy of Mr. Frank Hann's journal of his trip to this region in 1906. The country was then suffering from a severe drought, and most of the water-holes were dry. Hann mentions that, near the Warburton Range, grass which he had burned off two years previously had not sprouted. In some parts of the State there is sufficient salt-bush and other "top feed" to carry stock over a drought of two or three years, but in the Warburton Area there is very little scrub apart from mulga, which is generally too high for stock, so in times of drought a grazier would have very heavy losses.

Even if a regular rainfall were assured it is doubtful if the selection of country in the Warburton Area would be a profitable proposition. After leaving Laverton there is a journey of over 360 miles to Lilian Creek, where occurs the first and only permanent water on the route. As will be seen by a perusal of the section in Chapter I. dealing with water supplies, there are numerous water-holes between Laverton and the Townsend Range, but except in an unusually wet season, and then only for a short time after rain has fallen, the only waters that we saw large enough to water a mob of 500 cattle or a flock of 2,000 sheep were at Watt Creek and Manton Creek. Before the country described above could be taken up without undue risk, it would be necessary to open a stock route by sinking wells not more than twenty miles apart. This would mean sinking and equipping with troughs, windlasses, buckets, and ropes at least eighteen wells, and we do not think that under the most favourable conditions the returns to be derived from the settlement of the Warburton area by pastoralists would justify such an undertaking.

APPENDIX A.

SECTION I.

GENERAL ACCOUNT OF THE PETROLOGY OF THE DISTRICT AND CORRELATION OF THE ROCKS WITH THOSE FROM OTHER LOCALITIES IN CENTRAL AUSTRALIA, AND FROM THE WESTERN AUSTRALIAN GOLDFIELDS.

BY

R. A. FARQUHARSON, M.A. (OXON), M.SC., F.G.S.

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I.—GENERAL ACCOUNT OF THE PETROLOGY OF THE DISTRICT.

Well over one hundred specimens have been collected and microscopically examined. From the object of the expedition and from the circumstances which affected the accomplishment of that object, it was, of course, not possible to carry out a detailed geological survey of the country traversed, and, in consequence, the evidence obtainable with regard to the relations between the various rock types is necessarily not complete. Sufficient, however, has been obtained to enable a fairly clear conception to be formed of the petrological constitution of the District.

Full descriptions of the rocks examined, together with several micro-photographs, are given subsequently in Section II.

A.—CLASSIFICATION OF THE ROCKS.

1. Acid Porphyries.
    - (a) Acid Porphyries with phenocrysts.
    - (b) Granular Porphyries.
    - (c) Granite Porphyry.
    - (d) Micropegmatite.
    - (e) Black Porphyry and Porphyrite.
2. Granites, including the Pink and Grey varieties.
3. Granulites and Gneisses of Cohn Hill and Mount Aloysius.
4. Greenstones.
5. Basic Plutonic and Dyke rocks—
    - (a) Plutonic Intrusives.
    - (b) Rocks of Doleritic habit.
6. Rocks of Volcanic Origin.
7. Rocks of Clastic and Sedimentary Origin.

B.—GENERAL REMARKS ON THE VARIOUS SUBDIVISIONS.

1.—The Acid Porphyries.

These rocks (amongst which is included a somewhat doubtful porphyrite) attain a very considerable development in the Warburton Area, constituting part of the Warburton Range and extending eastwards from it to the vicinity of Barrow Range. They run generally in bands in a roughly east and west direction; are bounded on the south by the Greenstones and Sediments and on the north by the Pink Granite. Their detailed distribution has been already given in Chap. III., Sec. 2, and may be seen by reference to Plates II. and III.

From the point of view of structure, the rocks have been found to occur in several well-defined groups which may be thus classified:—

(a) The Acid Porphyries with phenocrysts.
(b) The Granular Porphyries.
(c) The Granite Porphyry.
(d) The Micropegmatite.
(e) The Black Porphyry and Porphyrite.

(a) *The Acid Porphyries with phenocrysts.*

These are, in nearly all cases, extremely fine-grained, felsitic or flinty rocks varying in colour from purplish-black, through liver-brown and dark-grey to light-grey, pink and reddish tints. In rare instances a profusion of phenocrysts gives them a somewhat coarse-grained appearance. While some specimens consist of a few pinkish felspar phenocrysts in a blackish or brownish ground-mass, there are all gradations from these through specimens with only felspar phenocrysts, and others with a few quartz phenocrysts in addition to the felspar, to specimens, such as [$\frac{1}{1145}$], consisting of numerous, quite large, pink felspar phenocrysts of square and columnar form, and many phenocrysts of quartz. The phenocrysts of felspar are all fairly fresh and the species is generally orthoclase, though in some specimens, notably [$\frac{1}{1148}$], there appears to be an intergrowth of two species.

Quartz phenocrysts are absent from some of the rocks, occur in small numbers in others, and in others again they are nearly as common as the felspars. They are always smaller than the felspars. In two specimens [$\frac{1}{1108}$] and [$\frac{1}{1140}$], they have a distinct blue tint. Frequently they show embayment by the ground-mass and, in a few instances, resorption of the margins.

Ferro-magnesians are either absent altogether, or present in only small amount. Chloritic scales or strings occur in some, e.g., [$\frac{1}{1144}$], [$\frac{1}{1086}$] and [$\frac{1}{1082}$], and rarely, as in [$\frac{1}{1145}$], a ragged more or less fibrous plate of pale-green hornblende. In one specimen, [$\frac{1}{1140}$], in which there are quartz phenocrysts to the exclusion of those of felspar, there are numerous small grains of pink garnet.

The structure of the rocks exhibits a considerable degree of variation. In some cases, the ground-mass is micro-crystalline, but in many it varies from point to point in the one section, some portions being holocrystalline mixtures of small quartz and felspar plates, others being microcrystalline, and others again cryptocrystalline. Moreover, in such rocks as [$\frac{1}{1082}$], [$\frac{1}{1084}$], [$\frac{1}{1074}$], and [$\frac{1}{1144}$], there is a structure resembling the flow structure of some rhyolites. In [$\frac{1}{1082}$] it is caused by fine strings of chloritic scales with distinct parallel alignment sweeping round the phenocrysts. It is due, in this case, however, rather to dynamic strain than to true flow structure. The same is true of [$\frac{1}{1144}$], in which the "flow" effect is even more pronounced. In [$\frac{1}{1084}$] a streaky appearance has been produced owing to some portions being cryptocrystalline and others coarser in grain. Moreover, there is a parallelism of the streaks, and, in some places, the pseudo-flow structure round the phenocrysts. Since, however, some of the quartz plates and some of the felspar forms are more or less disintegrated, with the production, in the case of the quartz, of eye-shaped areas it is probable that the apparent flow structure is again the result of dynamic stress on the rock during the process of consolidation. In [$\frac{1}{1074}$], the ground-mass consists of fine and coarse-grained bands or streaks, and the latter are curved and wavy. The alternation of fine and coarse streaks or bands undoubtedly suggests an origin of the rock from a flow, but as there are again in the rock pronounced effects of dynamic stress, the structure has probably originated in the same way as in [$\frac{1}{1084}$].

The structure of two specimens, [$\frac{1}{1085}$] and [$\frac{1}{1086}$] calls for special mention. In the former, [$\frac{1}{1085}$], which carries a few ragged partially resorbed phenocrysts of clear quartz, the ground-mass consists of very little quartz and much felspar in ragged plates and numerous curved, feathery, tufted, wavy and divergent forms which are probably perthitic intergrowths. Many of the forms show a near approach to a radial structure and hence to a spherulitic appearance, but no true spherulites or pseudospherulites were observed. The ground is thus very similar to that observed in some granophyres.

In the latter, [$\frac{1}{1085}$], the ground-mass consists in places of a microcrystalline mass presumably of quartz and felspar, obscured by a fine greyish or pink dust, in others, of streaks or cryptocrystalline patches undulating through the former and more densely charged with pink dust and obviously curving round the felspar phenocrysts in a manner observed in rhyolites. The variation in the ground-mass, the streaky or "flow" structure, and the nearly isotropic nature of the streaks indicate affinities with rhyolitic flows and suggest that the ground-mass was originally glassy. The rock is most closely allied to the felsophyre of Rosenbusch, and its peculiarities have probably been caused by dynamic strain during consolidation.

These phenocrystal porphyries, therefore, vary from felsitic varieties with felspar or quartz phenocrysts or both, through granophyric porphyries to varieties little different from rhyolites. They are all, however, quartz porphyries, since those with an absence of quartz phenocrysts still have quartz as a constituent of the ground-mass.

(b) *The Granular Porphyries.*

These rocks do not occur usually as dykes, but they are seen merging into dyke porphyries at the north-west end of the Eveline Dyke, and elsewhere, and in some places also into the Pink Granites (see page 92). The specimens are characterised by a fine granular structure and an absence of phenocrysts. They are greyish-pink or dark-grey with a reddish tinge, fine-grained, and consist of a granular mass of quartz and felspar plates. In one specimen, [$\frac{1}{1136}$], there are enclosed grains of pink garnet, while in both [$\frac{1}{1158}$] and [$\frac{1}{1087}$] there are a few small grains of green hornblende and small scales of green chlorite.

(c) *The Granite Porphyry.*

This rock, of which [$\frac{1}{1087}$] is a specimen, and which is fully described later, is a very coarse-grained pink granitic rock in which large pink felspar crystals and occasional small quartz crystals appear in a finer-grained ground-mass. There is a small amount of black chloritic mineral.

Both in hand specimens and under the microscope it presents a striking resemblance to the pink granites. The felspars are extremely coarse and platy, they are almost all orthoclase, there is a small development of greenish hornblende, and intergrowths of quartz and felspar are common. On the other hand, there is no doubt whatever that the rock is a porphyry, since well-defined phenocrysts of quartz are observable surrounded by an intergrowth of quartz and felspar. This intergrowth, while in some cases like the graphic intergrowth of granites, is in others rather similar to that observed in certain granophyres. The rock, therefore, is to be regarded as a coarse granite porphyry that is either a margin to or an apophysis from the pink granite mass, and that is probably an intermediate stage between the latter and the pink quartz porphyries.

(d) *The Micropegmatite.*

This peculiar facies, from the top of a cairn on Mount Squires, is an apparently rather coarse-grained greyish-pink granitic rock consisting chiefly of plates of felspar. Its remarkable structure in section is fully described in Section II., so that only the following characters will be given here.

It is composed almost wholly of micropegmatitic intergrowths of quartz and felspar. These in some cases are identical with the graphic intergrowths observed in certain granites; in others they appear exactly similar to the minute pericline striations visible in karlsbad twins of plagioclase, while in others again, they form plates of innumerable dots or grains, which are probably the result of sectioning the striae at right angles to their length. Frequently there is a gradual passage from a minute radial or striated intergrowth into the coarser graphic variety, and there are patches of micropegmatite frequently showing the outlines of idiomorphic crystals, which are surrounded by granular intergrowth. Only rarely do normal felspar plates occur, though large quartz plates are not uncommon in portions of the slides.

(e) *The Black Porphyrite.*

These are represented by [$\frac{1}{1102}$] from about 6½ miles north-east of Fort Mueller, and [$\frac{1}{1106}$] from about a mile east of Camp 55. The former, [$\frac{1}{1102}$], is a very fine-grained, dark-grey, felsitic rock with small phenocrysts of felspar and with a yellowish weathered crust. Though the rock is obscure in structure, it is a fine-grained, considerably weathered, felsitic quartz porphyry or porphyrite.

The latter, [$\frac{1}{1106}$], is also a dense black, fine-grained felsitic flinty rock with occasional phenocrysts of greyish felspar. There are occasionally large, often cracked and broken felspars in a microcrystalline ground of felspar and apparently quartz, obscured by a fine dust of chloritic scales, zoisite and calcite grains and some iron ore. The phenocrysts are mostly altered to zoisite grains and needles. The constituents of the ground have clearly been drawn out into fine lines or strings which are minutely faulted across. The rock is rather intermediate than acid in composition, and is more a sheared acid porphyrite than a porphyry.

Inter-relation of the Porphyry groups.

As already remarked, the similarity between the granite porphyry and the pink granites is so marked as to suggest that the former is but an apophysis of the latter. The granular porphyries appear to occur as a fringe to the coarser pink granite, while in places they are found merging into the phenocrystal porphyries. Owing, however, to the unavoidable lack of detailed observation, it is not possible to state whether they are to be regarded merely as granular varieties of the phenocrystal porphyries or granite porphyry produced owing to differences in the circumstances of crystallisation, or as granulated varieties of the pink granite porphyry or pink granite itself produced by dynamic metamorphism and consequent recrystallisation. There is no doubt, however, that all these varieties are genetically connected. The micropegmatite must be regarded both from its mineral composition and its field occurrence as a variety of the phenocrystal porphyries.

The black porphyry [$\frac{1}{1102}$] though in some respects differing from the others, has several points in common with them, and may be regarded as an extreme variation of the felsitic quartz porphyries.

The black porphyrite [$\frac{1}{1106}$], however, appears to differ so considerably from the others both in appearance and composition, that it is probably to be regarded as a member of a different series of dykes, though its genetic relationships are at present unknown.

2.—The Granites.

These rocks are conveniently though only superficially divisible into two groups, the pink granites and the grey granites, of which the former occur, broadly speaking, west of Cohn Hill, and the latter east of it.

The pink granites vary in colour from the pink to flesh red. Though a few varieties such as [$\frac{1}{1133}$] are fine-grained, most are medium to very coarse-grained with large platy crystals of reddish felspar. In general, felspar is in excess of quartz, and ferro-magnesians are only sparsely developed. The felspar species present are orthoclase and microcline with a subsidiary plagioclase sometimes enclosed in the microcline plates. An incipiently foliated structure is at times noticeable, particularly in [$\frac{1}{1064}$], and several specimens show partial granulation of the colourless constituents. Intergrowths of felspar and quartz occasionally occur, but only in small patches. They are noticeably coarse in [$\frac{1}{1132}$.]

The ferro-magnesian is generally biotite in a few brown flakes, but green chloritic flakes and strings are not uncommon. In some instances, notably in [$\frac{1}{1066}$] and [$\frac{1}{1133}$] there is a development of green hornblende in addition to the biotite.

The structure is usually coarse-platy, but dynamic deformation effects are noticeable, such as partial granulation of quartz and felspar, irregular extinction in these minerals and occasional incipient foliation.

The grey granites, from which any pink or reddish tint is absent, show all gradations from fine-grained varieties to extremely coarse-grained rocks in which the felspars are an inch or more in length and breadth. Most of the specimens obtained, however, are coarse-grained, greasy grey in appearance, highly felspathic, with little quartz and with only a small development of ferro-magnesians. In one specimen from the Amy Giles Rocks, the quartz has a heliotrope tint. Foliation is scarcely noticeable in any of the rocks in hand specimens, but in the rock masses in the field pronounced regional foliation can be traced, a fact indicating that though the rocks appear in hand specimens as granites, they are in reality granitic gneisses.

The felspar species present are, as in the pink granites, chiefly microcline and orthoclase with subsidiary striped plagioclase occasionally occurring in zoisitised and kaolinised columnar crystals enclosed in the microcline plates. Quartz is sparsely developed, is always much less common than the felspar and, being often squeezed in between the felspar plates, is then rather interstitial than platy. Rarely, small quartz grains are enclosed in the microcline in poecilitic fashion. Quartz-felspar intergrowths are not uncommon. They occur mostly in small rounded areas and, in one instance especially, in [$\frac{1}{1117}$], in which they appear as thin, more or less parallel quartz rods or tubules in felspar, between large plates of orthoclase or microcline and the plagioclase, they closely resemble the myrmekitic intergrowth of Sederholm.

The ferro-magnesians are again chiefly biotite in small brown flakes, at times altered to green chlorite, but there are also in some cases, particularly in [$\frac{1}{1113}$] and in [$\frac{1}{1116}$], undoubted plates of green or greenish-brown hornblende associated with the biotite.

In one instance, viz., in the rock from Mt. Gosse, [$\frac{1}{1113}$], there is a remarkable development of pink garnet in fine granular aggregates.

All varieties of the grey granites afford evidence of dynamic strain. This is most clearly shown in [$\frac{1}{1116}$] in which an enormous amount of mechanical deformation has been produced. The quartz and felspar plates are partially crushed, there is pronounced uneven and wavy extinction, secondary lamellation in the felspars, and granulation of both quartz and felspar. Moreover, to judge from the sections the stress seems to have operated along certain well-defined zones, and it is probable that these zones are coincident with the regional foliation of the gneiss. A peculiar rod-like structure in the felspar of the Mt. Gosse rock, resembling some perthitic intergrowths may be the result of the mechanical deformation.

Relation of the two groups.

It will be evident that the rocks of both groups are biotite-microcline or biotite-hornblende-microcline granites, and that their structure and composition are so closely similar as to suggest that there is a close genetic connection between them. The occasional presence in the grey granites of garnet aggregates, though apparently constituting a distinct difference between them, cannot on closer examination be regarded as such since garnet does not occur in all the grey granites, and garnet has been discovered both in the fine granular greyish-pink porphyries referred to quartz-porphyry, and in the foliated pink granitic gneisses. In certain localities, again, there appears at first sight to be a structural difference between the members of the two groups, viz., a foliation in the grey granites. Careful observation, however, proves this difference to be more apparent than real. In many localities, the grey granite exhibits a decided gneissic banding or foliation extending for considerable distances. In others, however, this foliation is not visible at all. Moreover, in most places, the pink granite is found to be foliated. The differences in structure, therefore, like those in colour, can at present scarcely be regarded as of much moment in face of the pronounced general resemblances.

Whether, however, the two granites are of the same age, or whether the pink granite is a later facies from the same magma that produced the grey, cannot on the evidence at present available be determined.

The pink granite, it may be remarked, appears to be connected through the coarse-grained granitic porphyry [$\frac{1}{1087}$] with the pinkish quartz-porphyries of the Warburton Area, and it is probable that these porphyries are either apophyses from the magma of the pink granite or later intrusions from the same magma.

Two of the granite specimens deserve mention, though they were collected about two hundred miles west of the Warburton Area. Of these, one from Point Uhr is a pale pink biotite microcline granite. The other from Point Salvation is mineralogically different from any of the granites described above. It is a rather dark-grey, coarse-grained rock with greyish or faint pink felspars in a finer-grained mass highly charged with scales of biotite. It consists of large plates of felspar surrounded by smaller plates and columnar crystals of felspar and plates of quartz, with scales of biotite, occasional ragged plates of green hornblende and large and small grains of sphene. No microcline was observed in the sections, though crystals apparently of orthoclase are not uncommon. The rock is a rather coarse-grained biotite-hornblende granite with a tendency to porphyritic structure. It differs from the preceding granites in the prevalence of biotite, in the occurrence of green hornblende, in the structure, in the absence of microcline and in the presence of a considerable amount of sphene. On the whole it shows characters suggesting a closer resemblance to granodiorites than to granites.

3.—The Granulites and Gneisses of Cohn Hill and Mount Aloysius.

The rock at Cohn Hill, which extends in a north and south band to Minnie Hill, is of a comparatively rare type, and one hitherto unrecorded from Western Australia. In hand specimens it is a fine-grained, dark bluish-green, apparently siliceous rock with numerous round crystals of red garnet, and a rough imperfect foliation. The rock, which is fully described in Section II., consists of garnet, hypersthene, quartz, felspar, biotite, iron ores, zircon, and a little doubtful green spinel. The structure is essentially granular, the result of granulitisation and recrystallisation of the colourless constituents, and of the occurrence of the pyroxene in granular forms. The rock is a garnetiferous hypersthene gneiss or granulite.

The significance of the occurrence will be discussed after an account is given of the other outcrops.

At Mount Aloysius, there are occurrences of two unusual rocks:

From the top of the Mount, specimens were obtained of a rock showing indistinct reddish garnets without crystal faces, some quartz, and small thin columnar or acicular crystals well cleaved and with adamantine lustre. On the weathered surfaces, the latter are visible sometimes in small bundles. The appearance of some of the specimens very closely resembles that of brownish varieties of the ferruginous jaspers so common in the goldfields of Western Australia. The rock, which is fully described in Section II., is a dynamically strained garnetiferous-sillimanite-quartz rock of granulitic character.

Again, about 1½ miles west-north-west from the Mount, and outcropping in a watercourse, specimens were obtained of a fine-grained white felspathic rock with faint suggestion of foliation, with a strong development of small red garnets, and with a little clear quartz visible in places. Under the microscope, this rock shows indistinct bands of fine-grained kaolinised felspar and quartz, separated by highly quartzose bands in which the quartz occurs in elongated ragged strips that are remains of larger quartz plates partially granulitised. Pink garnet is very common, in large and small rounded forms sometimes enclosing quartz grains. The original structure is not clear, but appears to have been either coarse platy, or porphyritic with felspar phenocrysts. The rock is a granulitised, highly garnetiferous, quartz-felspar facies now in course of alteration to a garnetiferous granitic gneiss or granulite.

Finally, some distance to the west of Mt. Gosse, occurs a fine grained grey, foliated, garnetiferous-sillimanite-gneiss, in which quartz and felspar are not uncommon. The felspar is in part orthoclase, in part microcline, though the "gridiron" structure observed in the latter may be, at least in part, the result of dynamic stress.

All these rocks occur as bands apparently in the grey gneissic granite, and, since the grey granites themselves all show more or less pronounced evidence of dynamic strain, and the granite at Mt. Gosse has a considerable development of granular garnet, it would appear that they are due to a recrystallisation of the granitic rocks in certain zones along which shearing has been most intense.

Two of the specimens, however, the garnetiferous hypersthene-granulite, and the white garnetiferous-granulitic rock from near Mount Aloysius are of particular interest. Though the amount of available material of the former is too small to allow of a chemical analysis being made, nevertheless, from its composition and structure, it would appear to have been originally of granitic character. Moreover, there is an undoubted resemblance between it and some of the acid varieties in the Charnockite Series of Southern India, described by Dr. Holland, and in particular to the varieties that have been dynamically metamorphised with the production of garnets and a gneissose structure. Further, the white garnetiferous granitic rock from the watercourse west-south-west of Mount Aloysius presents certain distinct points of similarity with the cream-coloured friable rock of the Charnockite Series referred to by Dr. Holland as the Garnetiferous Leptynite.

There is reason for believing, therefore, that in Central Australia, just as there are occurrences (to be described later) of olivine norites and allied rocks practically identical with those from the Cuddapah series of South India, so there is a counterpart of some at least of the members of the Charnockite Series. Should further investigation of this very inaccessible region of Australia confirm this belief, the evidence already at hand from the petrological affinities of these isolated relics of the ancient Gondwana Land will be considerably strengthened, especially as Lacroix has recently discovered members of the Charnockite Series of India on the Ivory Coast of Africa, and, according to Gregory, some members of it—the hypersthene granulite and a hornblende hyperite—have been found in Benguella on the West African Coast. It is worthy of remark, however, that there is no occurrence in the Charnockite Series of India of the sillimanite-gneisses of Central Australia, while these rocks form an important member of the "Normal Granulites" or Saxon Granulites of German petrographers.

It is proposed to deal more fully with the significance of the occurrence of the olivine norites, the hypersthene-granulites and the garnetiferous gneiss or granulites of Central Australia in a separate paper.

4.—The Greenstones.

The rocks included in this division comprise those which consist chiefly of hornblende either in fibrous or in platy forms, and either fresh or chloritised, and felspar in columnar platy or granular form, and which are of some shade of green in colour, though the green tint may be modified by the presence of epidote or zoisite or oxide of iron. The distinction between these rocks and those described subsequently as volcanics is rather difficult to establish. The specimens of both divisions afford evidence that the original ferromagnesian was augite; they are much altered by epidotisation, carbonation, etc., and in the case of most of the greenstones and of all the volcanics the structure is more or less recognisable as originally ophitic. Moreover, owing to the circumstances under which the expedition was carried out, detailed field work on the outcrops was impossible. For these reasons, therefore, it is quite possible that, as subsequently remarked in connection with the volcanic rocks, some of the specimens placed among the greenstones are really non-vesicular varieties of the former. The facts, however, that the original ferro-magnesian is now represented wholly or almost wholly by green hornblende, and that the latter is in the fibrous form commonly regarded as due to dynamic metamorphism, have served as the positive criteria for the differentiation of the greenstones.

The rocks extend from the Warburton Range eastwards, and are apparently intruded by a series of roughly parallel porphyry dykes, which strike broadly east and west. The majority are medium to fine-grained fibrous epidiorites and amphibolites that have been derived from dolerites or gabbros, that have been very considerably epidotised and zoisitised, and in which the original augite has been in nearly all cases completely altered to fibrous hornblende or to chlorite. Despite the common alteration, however, in most of the rocks, relics of original ophitic structure are still preserved. One specimen, $[\frac{1}{1123}]$ from near Mount Herbert, is noticeably sheared. Another $[\frac{1}{1049}]$ from half a mile south of Camp 42, is very coarse-grained and resembles the coarse pegmatitic facies of the quartz-dolerite of Kalgoorlie. In both $[\frac{1}{1123}]$ and $[\frac{1}{1044}]$ from near Miller Hill, there is a close resemblance both in structure and composition to the fine-grained fibrous zoisitic amphibolite or epidiorite, $[\frac{1}{1318}]$, from Meekatharra, and the fine-grained amphibolites from Kalgoorlie. In $[\frac{1}{1118}]$ from Frank Scott Hill, which is a uralitic epidiorite, there are remains of original augite.

Especially noteworthy is a specimen $[\frac{1}{1070}]$ from five miles north-north-east of Camp 45, which proves to be a scapolite-amphibolite, the first recorded occurrence of such a rock in Western Australia. The rock itself is medium-grained and dark-green in colour, consisting of large irregular plates of green hornblende, with a smaller development of plagioclase felspar in plates and columns. The scapolite occurs as thin veinlets along the twin planes of the felspar, and as irregular small patches in the plates and columns themselves. The changes by which plagioclase-felspar has been altered to scapolite have been described by Judd. According to him, liquids under pressure and containing chlorine in some form or other, produce cavities by solution along the twin planes of the felspar, which become filled by supersaturated solutions of sodium chloride. At a subsequent period, dynamic stress causes a conversion of the mixture of plagioclase felspar and sodium chloride into scapolite. Now, results of dynamic stress, viz., crushing of the hornblende plates, irregularity of extinction in the quartz and felspar, and partial granulation of the latter are distinct in the rock, $[\frac{1}{1070}]$. There is in it an unusually large development of needles of apatite, in all probability the chlorine variety, and the felspar of the rock is a lime-soda species. It is, therefore, most probable that Judd's explanation accounts for the origin of the mineral in this rock.

The scapolite-amphibolites from India, described by Dr. Holland, are apparently more severely crushed and granulitised than is the case with $[\frac{1}{1070}]$, but, on the other hand, scapolite is evidently more abundant in the rocks.

Included in this division are two specimens from Mount Sefton, which occur about two hundred miles to the west of the Warburton Range, and are typical greenstones, similar to those from the known greenstone areas of the Western Australian Goldfields. One, $[\frac{1}{1024}]$, is a fine-grained dark-green minutely acicular and foliated epidiorite, and the other, $[\frac{1}{1025}]$, is a rather coarse-grained, dark grey-green, sheared epidiorite. They are both probably facies of the same rock mass.

5.—Basic Plutonic and Dyke Rocks.

These rocks may be classified in two groups:—

(a) Plutonic Intrusives, or rocks of Plutonic habit occurring apparently as large masses.

(b) Rocks of Doleritic habit, occurring demonstrably as dykes.

(a) *Plutonic Intrusives.*

Four specimens referable to this group were collected, three from the Cavenagh Range—$[\frac{1}{1099}]$, $[\frac{1}{1098}]$ and $[\frac{1}{1101}]$—and one from the east end of the Blackstone Range—$[\frac{1}{1107}]$. Of these, the first two from the Cavenagh Range are black, rather coarse-grained rocks, the third (from Fort Mueller) is finer in grain and shows light-grey plagioclase evident to the naked eye, while the specimen from the Blackstone Range is very coarse-grained and greyish-black in colour. All the rocks, which are fully described in Section II., are fresh, holocrystalline, and even-grained, with greasy lustre and numerous reflecting surfaces of columnar twinned plagioclase, and in all there is a preponderance of felspar over the ferro-magnesians. The freshness of the rocks is remarkable, for, though there is occasionally an alteration of olivine and iron ore, there is no trace of such alteration products as chlorite,* epidote, saussurite or sericite, and only occasionally is there a very slight development of kaolin. In this respect, the rocks are markedly different from the Greenstones already described and even from the majority of the basic dolerite dykes to be described subsequently. They are all of gabbroid type, though, owing to the fact that sometimes an ophitic relation obtains between the ferro-magnesian and the felspars, they may equally well be described as dolerites.

The chief minerals present are plagioclase, hypersthene, olivine, diallage and hornblende. The felspars which in all cases form the bulk of the rock are in large columnar finely twinned forms either quite fresh or rarely faintly turbid from kaolinisation. The species present is invariably a basic one, basic labradorite or bytownite. In $[\frac{1}{1098}]$ the felspar is so far predominant that the rock approaches an anorthosite in composition. The characters of the ferro-magnesians differ in different rocks. In $[\frac{1}{1099}]$, in which there is only a small development of coloured minerals, the chief is hypersthene in grains and anhedral forms often in ophitic relation with the felspar. The mineral is generally markedly pleochroic in pink to pale green tones, and sometimes exhibits a distinct schiller structure. There are in addition anhedral plates of monoclinic pyroxene often with a border of hypersthene and some granular forms referred to olivine.

In $[\frac{1}{1098}]$ the hypersthene is in rounded grains and irregular plate forms generally without schillerisation. Associated with it, but mostly in anhedral forms, is a schillerised colourless diallage. In some cases, small grains of hypersthene occur in the diallage, evidently an intergrowth of the two minerals, which are easily distinguishable by the pleochroism of the former, by the different optical orientation, and by the absence of schiller structure in the hypersthene. Plates of unschillerised diallage, however, are not uncommon. In addition to these minerals and in common association with them are rounded grains of olivine often with slight traces of schiller, and sometimes almost surrounded by a rim of hypersthene.

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* Rarely a few flakes of green chlorite are observable.

In $[\frac{1}{1107}]$ the ferro-magnesians are more common, olivine occurs frequently in granular as well as tapering forms, and often there is a border of hypersthene between the olivine and the felspar. A faint schiller is noticeable in the olivine, a brown-red staining, and a partial decomposition to a brown-red mineral referred to iddingsite. Moreover, associated with the hypersthene are occasional plates of greenish-brown hornblende which are probably original. Ophitic structure is distinct in the rock.

In $[\frac{1}{1101}]$ the ferro-magnesians are nearly as common as the felspar. There are rounded grains and plates of hypersthene with occasional plates of diallage in which orthopinacoidal twinning with a basal striation has produced a "herring-bone" structure. Grains of hypersthene occur enclosed in diallage, and the two minerals are generally closely associated in a pyroxene aggregate. The rock differs from the others of the group in the apparent absence of olivine. It shows a remarkably close resemblance to the norites from Norseman, and from several other localities in the State, and there is no doubt it is genetically the same rock.

These four specimens are, therefore, clearly but variants of one original basic gabbroid or doleritic magma. They are remarkable for the pyroxene intergrowths noticeable in them. Reference to a paper by J. A. Thomson,* on Rock Specimens from Central and Western Australia,* shows that he had already identified rocks of exactly similar nature from the Cavenagh Range; and since he has described in full the pyroxene intergrowth, the relation between the rocks, the significance of the discovery of this group, and the relation between it and the Norseman Norite dykes, there is no need here to enter on further discussion of these points.

(b) *Rocks of Doleritic habit.*

In contradistinction to the rocks of the previous group, all but one of these have been observed occurring as dykes intruding rocks of different identity. Taken seriatim, they are:—

1. A rather fine-grained micropegmatitic quartz-dolerite with flakes of biotite, intrusive into the coarser-grained biotite-microcline-granite $[\frac{1}{1099}]$. In this rock the chief constituents are colourless augite and basic labradorite in ophitic relation with one another. The augite shows in places an altered margin of green chlorite or green chloritic hornblende. There are small areas of quartz-felspar micropegmatite, a few small interstitial plates of quartz, occasional flakes of biotite, apatite needles and large grains of ilmenite or titanomagnetite.

2. An ophitic olivine dolerite, intrusive into the granite $[\frac{1}{1134}]$. This is a fresh, medium-grained black rock with numerous reflecting surfaces of augite and felspar. The augite is in anhedral plates of a greyish or violet tint, extremely cloudy or opaque from the presence of a fine dust, and sometimes schillerised.

The olivine is in rounded, oval and irregular grains, at times with a faint schiller, and sometimes decomposed with the same products as in the plutonic olivine-norites. The felspar is abundant, in columnar crystals, forming a plexus. The species is bytownite. Apatite needles and ilmenite grains are not uncommon and there are a few scales of biotite, but quartz is not present.

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* Thomson, J. A.: Rock Specimens from Central and Western Australia. Jour. and Proc. Roy. Soc., N.S W., Vol. XLV., 1911.

3. The ophitic quartz-dolerite intruding the granite of which [$\frac{1}{1064}$] is a specimen. This is a fairly fresh, medium-grained rock similar in appearance to the olivine dolerite just mentioned, but somewhat stained by iron oxide. The chief constituents are again augite and felspar, the former in large irregular plates of greyish violet colour, and the latter in columnar forms in ophitic relation with the augite. The felspar species is bytownite. There is a little interstitial quartz in small grains and plates.

4. A fine-grained ophitic dolerite occurring as a dyke in the gneiss forming hills near Mount Aloysius. The rock is of black basaltic appearance, and consists of anhedral forms of pink augite in a plexus of somewhat micacised felspars. In structure and composition it is identical with the dolerite occurring as a dyke at Sandstone, and at Paddy's Flat at Meekatharra.

5. A fine-grained amphibolised dolerite, occurring, according to the field evidence, as a dyke intrusive into the olivine-norite [$\frac{1}{1097}$]. The rock is very fine-grained, nearly black and basaltic in appearance. Microscopically, it is much altered and consists of a dense mass of minute, nearly colourless, pale-green, fibrous prisms of hornblende, in which are thin short laths of turbid felspar. The fibrous hornblende has undoubtedly been derived from original granular augite. Strictly speaking, the rock should be classed amongst the Greenstones, but from its mode of occurrence and structure it is probably more justly considered in the present group.

Affinities of these Dyke Rocks.

According to Thomson,* the micropegmatitic quartz-dolerites—presumably the same as those occurring as dykes in the granite [$\frac{1}{1097}$]—are members of the related series of olivine norites. He regards them as the acid portions of the basic magma that gave rise to the norites. While there is no evidence of this relationship in the paper beyond certain microscopic similarities, and, presumably, analogy with localities in which quartz-dolerite facies occur as margins to basic gabbros, the view is to some extent supported by the occurrence, as dykes in the granite, of ophitic olivine dolerites. These rocks agree so closely, both in structure and composition, with the olivine-norites of the Cavenagh Range as to suggest that they are both not only genetically connected but probably contemporaneous; or in other words, that the magma which gave rise to the plutonic mass at the same time gave rise to the olivine dolerite dykes. If, then, the micropegmatitic quartz-dolerite represented an acid portion of the magma, it is feasible that dykes were formed of two types of rock differing considerably in chemical and mineral composition and yet contemporaneous and of the same origin.

On the other hand, since dykes of fine-grained amphibolised dolerites have been discovered clearly intruding the olivine norite mass at Cavenagh Range, it is certain that either all the dykes are not of the same series and age, or they are themselves an inter-related group and of different age from the norites. The small amount of evidence available points to the occurrence of at least two sets of dykes of different age.

It is remarkable that, as pointed out by Thomson, exactly similar rocks to the Olivine-Norite series have already been noted from South Africa and South India, and the question arises whether they have not all arisen from a magma which at the time of the breaking down of the Gondwana Continent was, as the result of the consequent earth movements, introduced into the pre-existing rocks at the same time in three different portions of the Continent yet remaining. This question it is proposed to discuss in a paper dealing with the probable occurrence of the counterparts of the Charnockite Series in Central Australia.

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* *Loc. cit.* pp. 307-8.

6.—Rocks of Volcanic Origin.

The identification of these rocks has been based chiefly on the occurrence of vesicular cavities infilled with epidote, quartz or calcite or mixtures of these, but also to a certain extent on the structure of the rock mass. Since, however, the rocks are all much decomposed, since some of the rocks do not contain vesicles, and since in these the chief indication of a volcanic origin is the presence of traces of two generations in the original ferro-magnesian, the differentiation of these rocks from the greenstones already described is a matter of considerable difficulty, and it is quite possible that, except in the case of the vesicular rocks, some to which a volcanic origin is ascribed, should really be included amongst the Greenstones, and that some of the latter may represent non-vesicular facies of some of the volcanics. The structure of certain members of these divisions is undoubtedly very similar, though, whereas in the greenstones the original ferro-magnesians have been altered chiefly to fibrous hornblende and chlorite, in the Volcanics they have been altered in most cases only to chlorite, while in some of the rocks ferro-magnesians appear to have been almost wholly absent.

The rocks have been found in the neighbourhood of Mt. Herbert; eight miles north-east of Depot Camp; 3½ miles east-south-east of Camp 46 near Hughes Creek; and at Table Hill. With the exception of the Table Hill group, they occur at the base of the Townsend Range Sedimentary Series.

The rocks are all fine-grained much altered—chloritised, epidotised, carbonated or ferruginous—dolerites with an ophitic structure more or less distinct.

The specimens from Mount Herbert comprise two that are vesicular [$\frac{1}{1122}$] and [$\frac{1}{1124}$], and one in which small black chloritic patches occur [$\frac{1}{1125}$].

Of the vesicular rocks, one [$\frac{1}{1122}$] is fine-grained and dark-green in colour with many small rounded yellow spots, some of which are epidotic, others zoisitic and others quartzose. From the form and composition of these spots they are much more probably vesicles than decomposed phenocrysts. The mass of the rock is a fine plexus of laths and small slender rods of felspar with the interstices occupied by black magnetite dust, with associated epidote grains. The structure of the mass is very similar to that in the dense black varieties of the Cue and Sandstone dolerite dykes.

[$\frac{1}{1124}$] is very similar both in appearance and structure to [$\frac{1}{1122}$], but the vesicular forms, instead of being almost entirely of yellow epidote, are chiefly of white calcite, though some granular epidote occurs with the calcite.

[$\frac{1}{1125}$] which is a medium-grained rock of a dull greenish-black colour, differs from the two former in showing no vesicles, but in place of them there are numerous small black chloritic patches and occasional crystals of calcite, and patches of yellow epidote. The mass of the rock is again a plexus of laths of felspar largely obscured, however, by fine scaly chlorite, granular zoisite and large and small grains of calcite. The black chloritic patches appear to represent phenocrysts of the original ferro-magnesian.

The rock from eight miles north-east of Depot Camp is fine-grained dull greenish-black with occasional blackish chloritic patches. It is again highly epidotised and zoisitised, but of indistinct character owing to advanced decomposition. The large chloritic forms are of doubtful origin, since it is not clear whether they are vesicular infillings or merely alteration products of ferro-magnesian phenocrysts.

The specimen from 3½ miles east-south-east of Camp 46 is a fine-grained, liver-brown basaltic rock with numerous small and large rounded vesicular epidotic forms. It consists, again, of a plexus of rods and laths of felspar with granular iron ore and frequent patches of epidote. Owing to the density of the rock and the amount of staining by iron ore, there is no trace of ferro-magnesian and it is possible that the rock originally contained none. The structure, however, closely resembles the ophitic, and the slides are very similar to those of the dense-black tachylitic margins common in connection with the Sandstone dolerite.

The Table Hill rocks, which are found constituting a small eminence in sand country considerably to the south of Mount Herbert, form a fairly well-defined series. They are all fine-grained, and though they show a variation in colour from dark-brown to light-grey, since the degrees of colour obviously depend on the presence of a greater or smaller amount of red oxide of iron, it is probable that they were all originally similar in appearance. Some of the rocks consist of fairly large anhedral and subhedral plates of colourless augite, with a considerable development of granular augite in ophitic relation with numerous small rods or laths of felspar, and with an occasional small phenocryst of felspar. Others show only granular and no platy augite, with a greater development of porphyritic crystals of felspar. Most noteworthy of all, however, are specimens which, in a fine-grained brownish-red mass, contain numerous rounded spherules or vesicles, some empty, others lined by thin quartz crystals as in geodes, and others wholly filled up by white quartz. The vesicular origin of these forms is beyond doubt, and this fact, together with the finely doleritic or ophitic structure of all the specimens, and the close similarity between them in both structure and composition indicates that all the rocks are of volcanic origin and but variations of the one rock-mass. The chronological relation of the series has already been discussed in Chapter III. of the Bulletin.

7.—Rocks of Clastic and Sedimentary Origin.

This two-fold division of the rocks has been adopted owing to the occurrence not only of true sedimentary rocks, but of probable tuffs and agglomerates which, though in origin connected with the Volcanic Rocks, are yet, both in structure and in field occurrence, intimately connected with the true sediments.

(i.) *The Clastic Rocks* include:—

(a) Specimens such as [$\frac{1}{1088}$] from the same locality from which specimens of a chloritised ophitic dolerite were obtained. This rock is dirty green in colour, fine-grained and much decomposed, with a fragmental and tufaceous appearance distinct in ordinary light. Microscopically in some respects it resembles a highly chloritic greywacke, in others a decomposed tuff or ashy agglomerate.

(b) Specimens of which [$\frac{1}{1085}$] is an example. In this case, the rock is dark-grey-green and fragmentary with a slightly sheared structure, and with fragments of various sorts and sizes easily visible. The matrix closely resembles that of a sedimentary rock, especially of a greywacke, while the included igneous and possibly volcanic fragments suggest a resemblance to some volcanic conglomerates. From the structure and composition of the matrix this rock is best interpreted as a sheared greywacke with enclosed igneous—in some instances probably volcanic—fragments. It is worthy of note that there is a similarity between this rock and the arkose with agglomeratic affinities from Mt. Yagahong, especially in the apparent sedimentary structure and the nature of the enclosed fragments.

(c) A black very fine-grained flinty rock [$\frac{1}{1105}$] obtained from a hill about a mile east of Camp 55. The structure and composition of this are obscured by a fine black, probably graphitic dust, and by a large development of brown-yellow biotitic or chloritic scales which are drawn out in strings as if by shearing. The rock, however, being apparently fragmental, is interpreted as a black graphitic and biotitic agglomerate.

(ii.) *The Sedimentary Rocks* fall into two groups, the Normal Sediments and the Metamorphic Sediments.

The Normal Sediments, which comprise the Townsend Range series, consist of:—

(a) Grits of various kinds, some of them much weathered sericitic quartz-felspar grits with enclosed rock fragments; others chloritic calcareous grits with the sedimentary character indistinct, and with the carbonate in process of alteration from a granular to a crystalline condition; others again, dull, grey-green, slightly sheared, earthy and chloritic and little different from greywackes; and finally, normal greenish quartz-felspar grits.

(b) Fine-grained pinkish compact granular quartzites.

(c) Conglomerates such as [$\frac{1}{1120}$], which are of dark-grey colour, consist of rounded black fragments of large and small size sometimes porphyritic and identical with the Warburton quartz porphyries, enclosed in a fine-grained, dark-grey, siliceous matrix, which is made up of round quartz and felspar forms themselves cemented together by a fine-grained quartz or quartz-felspar mosaic.

(d) Rocks best described as volcanic conglomerates, of which [$\frac{1}{1080}$] is typical. These are medium-textured fragmental rocks composed of liver-brown, blackish and greenish rounded and angular fragments in a cement that is generally fine-grained and greyish, but sometimes calcareous. The rocks resemble in outward appearance many "puddingstone" conglomerates. In section, the fragments comprise quartz porphyry, chloritised glassy forms, dense black andesitic forms, and various volcanic facies of andesitic or basaltic character. The matrix is not a true sedimentary one. It is extremely sparsely developed, and consists in part of nearly isotropic glassy material sometimes with indistinct flow lines, and in part of platy calcite and chlorite.

The rocks undoubtedly have close affinities with tuffs, especially in the character of the matrix, and, for this reason, should perhaps be described amongst the volcanic rocks, but, since most of the fragments are rounded, and since the rocks are intimately associated with the true sediments of the Townsend Range series, they have been included in the same division as the latter.

The metamorphic sediments are represented only by a very few specimens amongst the rocks examined, and their identity is somewhat doubtful. Included in the group are a white quartzite with indistinct slaty cleavage and a development of a cream-coloured or pale-reddish aluminous mineral doubtfully referred to andalusite; and a fine-grained yellowish-white intensely sheared micaceous (muscovite) schist, which may have been either a granular aplite or a felspathic quartzite.

II.—CORRELATION OF THE ROCKS WITH THOSE FROM OTHER LOCALITIES IN CENTRAL AUSTRALIA.

Owing largely to the extreme inaccessibility of Central Australia, little work has hitherto been done towards throwing light on the geological and petrological character of the region. Even what has been carried out consists chiefly of general accounts of expeditions, the labours of which were necessarily circumscribed by the exigencies of time, money, and the seasons, and in particular by the all-important question of water. Consequently, no opportunity has so far been afforded of undertaking any detailed geological survey over any area. Certainly, in a few cases, accurate identifications and descriptions have been made of specimens collected, but the value of these is discounted by the fact that in all but rare instances, the important question of the field relationships of the rocks has perforce been neglected.

Nevertheless, a perusal of the various publications hitherto issued relating to the geology of the region, especially in the light of the results of investigation of the petrology of the area traversed by Messrs. Talbot and Clarke's expedition to the South Australian border, shows that there is enough information at hand to allow of a general correlation of the rocks of the most of the important features, and hence to arrive at some idea of the general geological constitution of Central Australia.

The chief publications (with their authors) relating to the region, that need be considered here, are:—

1. The Horn Expedition to Central Australia, published 1896. Geology by Professor Ralph Tate and Mr. J. A. Watt, and Petrology by Mr. J. Smith and Mr. J. A. Watt.

Included in this is a complete bibliography of articles dealing with Central Australia, from 1863 to 1894.

2. The Country between the Everard Ranges and Barrow Range, and between the Barrow Range across the Victoria Desert to the Fraser Range; by Victor Streich. Trans. Royal Soc., S.A., Vol. xvi., 1892-1896, page 75, *et seq.*

Included in this are Supplementary Notes on Streich's collection by Prof. A. W. Stelzner, of Freiberg.

3. Rock-specimens from Central and Western Australia, collected by the Elder Scientific Exploring Expedition of 1891-1892, *i.e.*, by the Expedition of Streich; by J. A. Thomson. Trans. Royal Soc., N.S.W., 1910.

4. Geological Report on the Country traversed by the South Australian Government North-West Prospecting Expedition of 1903; by H. Basedow. Trans. Royal Soc. of S.A., Vol. xix., 1905, page 57, *et seq.*

5. The Geology and Prospects of the Region to the South of the Musgrave Ranges: by R. L. Jack. Geol. Survey of S.A., Bulletin 5, 1915.

The following is a brief *resumé* of the chief observations of the various authors:—

V. Streich:

The hills to the east and south-east of the Everard Ranges* consist chiefly of quartzites and sandstones.

Two small outcrops of primary rocks occur ten miles east of Barrow Range as isolated hills of granulite. He considers this granulite as part of the formation of the Townsend Ridges.

The Everard and Birksgate Ranges consist almost entirely of eruptive granite.

The granite is frequently intersected by dioritic dykes, which prevail in the country between Mt. Gosse and the Barrow Range, and in the Cavenagh Range the hornblendic eruptive rocks reach their maximum development, as these hills are entirely composed of them. In the

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* These and most other places not in the Warburton Area will be found in the frontispiece.

Cavenagh Range, occurs a diorite which, in spite of a striated appearance, he considers an eruptive. He has also found of less frequent occurrence and not largely developed, diabase intersecting granite and diorite, eurite in granite, a syenite at Skirmish Hill and Mount Squires, and porphyrites also at Skirmish Hill.

Stelzner, after examination of some of the rocks, notes that Streich's diorite occurring in masses west of the Everard Range is a quartzose diabase, and that various other diorites are olivine diabases. He also identifies a felsite porphyry from Skirmish Hill and Mount Squires, and a granulite resembling the Saxon granulites from 10 miles east of the Barrow Range.

J. A. Thomson:

All specimens examined by this writer came from localities between the Barrow Range and the Everard Range. The chief rocks he mentions are:—

A norite with marked fluxion banding from the Fraser's Range (in Western Australia).

A hornblende granite, probably belonging to the gneiss series with abundant orthoclase, from the northern part of the Blyth Range.

A rock from east of the Barrow Range resembling some of the brown jasper bars of the Western Australian Goldfields, of which he states that in some particulars the structure suggests a clastic origin, but, on the other hand, the nearly constant orientation of an unnamed mineral and an alternation of bands of clear mosaic with other bands containing magnetite and limonite, strongly point to a parallel structure developed *in situ*. It is reasonable to suppose the rock is a member of the gneissose series.

A rock from the Cavenagh Range, resembling the rocks of the auriferous area of Western Australia. It is a light-green fine-grained amphibolite.

An augite-lamprophyre from the Cavenagh Range.

Ten other rocks forming a distinct and related series largely form the Cavenagh Range. These are quartz-dolerite and olivine-norites with enstatite-augite.

Prof. Tate, Mr. J. A. Watt, and Mr. J. Smeeth:

The observation of these writers embraced the Macdonnell Range, the James, Waterhouse, George Gill and Levi Ranges, Ayers Rock and Mount Olga.

They divide the Pre-Cambrian, *i.e.*, those rocks overlain unconformably by the true sediments of the Ordovician, into three groups:—

1. Those of evident sedimentary origin.
2. Those about whose origin there is considerable doubt, including a great part of the gneiss.
3. Those that are clearly of eruptive origin.

The few rocks belonging to group 1, since they scarcely concern the purpose in hand, may be left out of consideration.

Among the rocks of group 2, they mention a very typical variety of gneiss occurring in the Macdonnell Range. This is strongly foliated, but the folia are not very persistent. The folia which consist of quartz, felspar and a few grains of biotite, are separated from each other by thick layers of biotite.

There are specimens of another gneiss which extends over a large area of the Macdonnell Range, and in which the quartz and felspar are not distinctly marked off into folia, and seem to be much crushed.

Another specimen from the Belt Range which rises abruptly out of the elevated area of the Macdonnell Range, is a gneiss with eyes of microcline embedded in a crushed mass of felspar, quartz, and a small amount of mica.

Among the rocks of Group 3, is a granite (the Oolgarna granite from the Hunt Range, which is an easterly extension of the Macdonnell Range), in which all the constituents, quartz, felspar, and mica are developed on an enormously large scale. The felspar is in part microcline and in part a soda plagioclase.

Included in this group is a gneissic granite from the Macdonnell Range. According to the writers, there is no doubt it is a granite which has undergone a certain amount of crushing, but not enough to make its origin a matter of doubt. It consists chiefly of microcline and quartz, often intercrystallised as in graphic granite. The rock, in hand specimens, does not appear to be foliated, whereas in the field a coarse-banded foliation was observed.

A similar gneissoid granite with large porphyritic microcline crystals was observed from Alice Springs, which are also in the area of the Macdonnell Range.

From the Oolgarna Claim, a granulitic pyroxene diorite with much hypersthene and uralitic hornblende was obtained.

In the neighbourhood of Ellery Creek, which rises on the northern edge of the Macdonnell Range, there are a large number of dykes of basic rocks intruded amongst the gneisses, etc. These dykes are chiefly olivine dolerites, olivine-dolerite with hypersthene (olivine-norite), amphibolised diabasic dolerite, fresh diorite, gabbro, and fine-grained dolerite.

Amphibolite was found at Claraville in the East Macdonnell Ranges, and uralitic amphibolite near the head of Ellery Creek, also in these ranges.

A microcline granitic arkose forms the whole of Ayers Rock, north of the Musgrave Ranges.

Finally, in pebbles in the conglomerate of Mount Olga are specimens of a beautiful, fine-grained, micro-pegmatite consisting almost wholly of intergrowths of quartz and felspar.

H. Basedow:

The writer describes the Musgrave Ranges, the Mann Ranges, Mount Gosse, the Tomkinson Ranges, Everard Ranges, Ayers Ranges, and the Indulkana Outcrop.

In the Musgrave Ranges the intrusive rocks vary from highly acidic to basic, the differences, however, between members of one and the same family being slight. The acid rocks are principally granitic, the greater bulk consisting of a rather coarse-grained porphyritic variety with large corroded crystals of a bluish felspar (orthoclase). On the eastern borders of the Range gneisses predominate.

Diorite dykes are very plentiful. Dolerite dykes are less common.

The metamorphic rocks show a gradation from a compact gneiss through quartzite, quartz schist, and schists of various kinds (mica, chlorite, epidote, garnet with numerous perfect crystals of garnet in a dark quartzitic schistose matrix).

An outlier of the Musgrave Ranges—Mt. Caroline—is composed of biotite granite with a slight tendency to foliation on the part of the mica. Large porphyritic corroded crystals of orthoclase predominate, the quartz being subordinate to the felspar. The rock is cut by a diorite dyke that runs as a black wall the entire height of the Mount.

In the Mann Ranges, the axis is in the same straight line as the axis of the Musgrave Ranges.

The igneous rocks consist chiefly of intrusions of granite forming the backbone of the Ranges. These disappear on the east under superincumbent gneisses. In places, the granite has been greatly shattered during solidification.

The metamorphic rocks consist of crystalline schists and gneisses extensively developed on the eastern end of the chain. The structure of the Range is a central core of granite intrusion, which has thrown the overlying beds into a series of single folds. An anticlinal directly conforms with the surface of the eruptive and consists of blue garnetiferous schist and gneiss.

At the north end of the Ranges, the country consists of compact gneiss with large bluish orthoclase crystals and folia of biotite, intruded by diorite dykes.

Mount Gosse is composed of an intrusion of granite within schistose to granitic gneiss, and traversed by diorite dykes.

In the Tomkinson Ranges, the dominant features are similar to those of the Mann and Musgrave Ranges, *i.e.*, igneous intrusions within crystalline gneisses. The intrusive rock, however, consists largely of gabbro accompanied by diorite dykes.

The Mount Davies chain includes a large intrusion of granular olivine-gabbro from dirty-green to faint-blue in colour.

The metamorphic rocks consist of gneisses, which in the north are of granitoid and foliated character, and in places garnetiferous.

North of Mount Davis, are outcrops of hypersthene-bearing granulite, compact and granular with little or no evidence of foliation on freshly fractured surfaces, though it is apparent on weathered faces. The rock has a peculiar olive-green, waxy appearance.

In the Everard Ranges, the igneous rocks consist of true granitic intrusions often with large porphyritic felspars, penetrating granitic gneiss. The granite at the borders of the intrusions has assumed a gneissic character, produced by movement of the rock after partial crystallisation. Diorite and pegmatite dykes occur.

The metamorphic rocks are granitic gneiss with a foliation rendered conspicuous by planes of dark-coloured biotite.

In the Ayers Ranges, the peaks are determined by intrusions of igneous rocks, in some cases granite, in others diorite dykes. Between the peaks there are disconnected rounded hills of metamorphic rock rising from a vast expanse of sand.

The igneous rocks are chiefly coarsely crystalline, sometimes porphyritic granite. About 15 miles south of Mount Cavenagh, there is a highly felspathic granite with light-red orthoclase. Diorite intrusions are exceedingly plentiful.

In the Indulkana outcrop, there are graphic granite, pegmatite and greisen and diorite dykes which cut the pegmatite. True granite is feebly represented by a coarsely crystalline rock with pink crystals of orthoclase, rather subordinate bluish quartz, and a greenish biotite.

Basedow has also given petrological descriptions of some of the rocks collected on his expedition. These include:

Granite from the Mann Ranges. This is a porphyritic granite, with large porphyritic felspars of dark-grey, greasy appearance. Biotite is surrounded by a broad band of closely set pink garnets. The felspar is a potash variety, and there are frequent micrographic intergrowths of quartz and felspar.

Granite from Mt. Sir Henry, Ayers Range. This is similar to the above, but contains no garnets, and there is a finely-twinned plagioclase as well as orthoclase.

Granite from the Musgrave Ranges. This is a hornblende-granite with both orthoclase and microcline and biotite, and with pink fractured garnets near the biotite.

Granite from the Everard Ranges. This is a pink granite, coarsely crystalline, with prominent pink orthoclase, dark-coloured mica and frequent micrographic intergrowths.

Gneiss from the Mann Ranges, south-west of Mount Samuel. This is a compact granitic rock with a tendency to foliation. The felspar is chiefly orthoclase and microcline, and there is a little micrographic intergrowth.

Olivine gabbro from Mount Davis.

Quartzite from Mount Chandler. This is a highly compact, fine-grained, white, siliceous quartzite breaking with a splintery fracture.

R. L. Jack:

This writer, who gives an account of the region to the south of the Musgrave Ranges in North-Western South Australia, states that the Pre-Cambrian rocks—which alone concern the present purpose—may be divided into three sections, the oldest complex of sedimentary and igneous rocks, the newer or Everard Range invading granite, and the extensive development of basic dykes which penetrate the rocks of both the earlier groups, but do not penetrate the Cambrian and Ordovician sedimentary formations. The first sections consist of gneiss, some granite mica schist and quartzite; and the gneiss appears to be derived in part from sedimentary rocks, in part from igneous rocks.

Felspathised rocks make up by far the greater bulk of the oldest terrain, and they range in character from felspathic schists through gneiss to typical granites. The latter, however, show more evidence of strain than is apparent in the later or Everard Range type of granite.

A considerable quantity of rhyolitic debris was found in Tietkens Birthday Creek on the eastern side of the Musgrave Ranges. It is fine-grained and contains felspar phenocrysts and fairly well-marked flow structure. In thin sections, the flow is extremely pronounced and many of the phenocrysts of felspar exhibit signs of strain.

Further, a sharply angular fragment of felspar porphyry was found 18 miles north-west of Mt. Illbillie in the Everard Ranges, near a large gabbro dyke. The ground-mass of the porphyry is dark-coloured and fine-grained, and surrounds fairly abundant felspar phenocrysts. While it is improbable from its shape that the specimen could have travelled far, no occurrence of the rock *in situ* could be found.

The basic dykes have a strike or trend about east and west. They range in size up to one or two hundred feet in thickness, and one was traced for six miles. The chief types of these found were:—

Biotite gabbro, from Mt. Ferdinand on the south-east end of the Musgrave Ranges.

Hornblende gabbro, from north of Moorilyanna Hill, which is south of Ayers Range. This rock contains violet augite and light-green hornblende.

Gabbro Amphibolite with augite largely amphibolised, from Indulkana Creek, just north-west of Mt. Chandler.

Olivine-mica-gabbro, from north of Mt. Illbillie in the Everard Ranges.

Ophitic olivine-mica dolerite, from Mt. Carmeena, near Mt. Illbillie.

Ophitic olivine dolerite, from seven miles north-west of Healy Springs, which are north-west of Mt. Chandler.

Fine-grained dolerite of basaltic type south-east of Mount Ferdinand, and in the Musgrave Ranges.

After a consideration of the foregoing *resumé* and a comparison of the features with those of the petrology of the Warburton District, the facts and conclusions which may be drawn are as follows:—

The Musgrave, Everard, Birksgate, Mann, Blyth, and Ayers Ranges and the Indulkana Outcrop consist of granite which is held to be intrusive into crystalline rocks that, though sometimes quartz schist, garnetiferous schist, chlorite, mica and epidote schist, are in most cases granitic gneiss frequently containing garnets. The Macdonnell Ranges consist of microcline gneiss and gneissic granite.

With the exception of the cases of the Everard Range and of the Indulkana Outcrop, the granite intrusions show a remarkable similarity both in outward appearance and in mineral composition and structure. The granite from the Musgrave Range is a hornblende granite with orthoclase, microcline and biotite and with pink garnets associated with the mica. The granite of the Mann Ranges is a porphyritic granite with large porphyritic felspars of dark-grey, greasy appearance, with biotite surrounded by pink garnet, and with frequent micrographic intergrowths. The granite of Ayers Range is a coarsely crystalline porphyritic type. The rock of the Blyth Range is a hornblende-granite of the gneiss series with abundant orthoclase. Moreover, the chief rock of the Macdonnell Range is in part a granite (Oolgarna Granite from the Hunt Range) in which all the constituents—quartz, microcline, and biotite—are extremely coarse, in part a microcline gneiss with "eyes" of microcline, and in part gneissic granite. The latter, too, which is undoubtedly of igneous origin, consists chiefly of microcline and quartz, and though the rock in the hand specimen does not appear to be foliated, in the field a coarse-banded foliation is to be observed.

After a comparison of these granites therefore, with each other and with those, especially, from Mount Gosse, and account being taken of the remarkable uniformity in strike of the Ranges mentioned, there is no room for doubt that the granites of which these ranges are mainly composed are both in origin and in age essentially the same rock; that this rock is a greyish, coarse-grained, biotite microcline granite, with or without granular garnet, with or without hornblende, and with or without a gneissose structure; and that the differences observed in it are merely local or such as are to be expected in a rock-mass outcropping at intervals over hundreds of miles of country.

In the case of the Everard Ranges and the Indulkana Outcrop, the granite is a coarse-grained pink variety with prominent pink orthoclase crystals. From the description of the rock, there is little doubt that it is identical with the Pink Granite of the Warburton Range and its neighbourhood.

In regard to the gneisses into which the granites are held to be intrusive, there are some facts of significance. In the Everard Ranges, the gneisses are foliated, but the intruding granite is also said to be foliated on the margins. In the Mann Ranges, the gneiss is a compact granitic rock with a tendency to foliation, with predominant orthoclase and with micrographic intergrowths; and in these ranges, also, gneisses on the eastern flanks include a blue garnetiferous schist. In the Tomkinson Ranges, though the intruding rock is not granite but gabbro, the gneisses or crystalline schists are granitoid, foliated and in places garnetiferous. Now, since garnetiferous schists and garnetiferous granitoid rocks and granulites have been described from Cohn Hill and Mount Aloysius, since the rock from Cohn Hill is a bluish-black garnetiferous schist which from the description given of the schist from the Mann Range may be identical with the latter, and since these rocks appear to have been derived by intense crushing rather from the plutonic, igneous, coarse, grey granites than from sedimentary rocks, there is good reason for believing that the so-called superincumbent or intruded gneisses are really more highly crushed portions of the apparently intruding granite. The strongly gneissic character of much of the granite of the Macdonnell Range, which is, indeed, in places a crushed microcline augen-gneiss, tends further to support this belief.

Streich, from his examination of a section at Turban Hill near the Birksgate Range, came to the conclusion that the granites were the result of metamorphism of sediments. He states:—

> "The basal part of the section consists of a metamorphic granite, the upper part of a quartzite, whilst the intermediate beds show a passage from one to the other. The succession from below upwards is as follows: granite containing quartz-pebbles, a silicofelspathic magma changing into quartzite, ferruginous quartzite, white-coloured quartzite."

Through the kindness of Mr. L. Glauert, of the Perth Museum, the present writer was enabled to obtain for examination a portion (27B) of one of the strata above the granite at Turban Hill from Streich's duplicate collection. This stratum is a pinkish-white, medium-grained granitic rock with somewhat rounded grains of quartz visible to the naked eye. Microscopically, it proves beyond doubt to be a rather coarse-grained arkose, formed from the debris of a granite. As it is in the highest degree probable that the other strata are but varieties (some quartzose, some felspathic) of this arkose, from Streich's own specimens there does not appear to be any evidence of the metamorphism he holds to have taken place.

In the matter of the age of the granites, Jack distinctly regards the Pink Granite of the Everard Range as of later origin than the Pre-Cambrian granites—presumably the coarse-grained grey granites, but beyond the fact that, according to him, the Everard granite shows less evidence of strain than the older type, there is apparently no published evidence for the view. The question is of interest in the Warburton Area where there is a considerable development of both the pink and —east of Cohn Hill—the grey varieties, and where from the remarkable similarity between them, they have been regarded as genetically connected. As already remarked, there is evidence for the existence of porphyry dykes very similar to those of the Warburton Area, both in the Everard Range and at Tietkens Birthday Creek to the north of it, and this close association of the pink granite and the acid porphyry dykes wherever found may, if the relative age of the dykes is borne in mind, be held to indicate not only a genetic connection between them, but a later origin of the pink than the grey granite.

The Cavenagh Range, and the Blackstone Range are apparently composed of basic plutonic igneous rocks of dolerite and olivine-norite type. The Mount Davies chain also includes a large intrusion of granular olivine-gabbro, which is obviously similar to the rocks of the three ranges just mentioned. A peculiar and important character of the rocks of these ranges is the presence in them of enstatite-augite.

The Barrow Range consists chiefly of the acid igneous micropegmatite, and Skirmish Hill, some distance to the east, is composed of the felsitic quartz-porphyry so strongly developed in the Warburton Range.

Everywhere intrusive into the granite and gneisses, from the Warburton Range to the eastern extensions of the Macdonnell Range, and, south of the latter, to Avers Range and the Indulkana outcrop, are numerous basic dykes which show remarkably similar characters in the different localities. Despite their number, they are all reducible to a few types, viz., diorite, amphibolite, amphibolised dolerite, hornblende and mica gabbro, dolerite, quartz dolerite, olivine dolerite and olivine norite. The most recent investigations of their nature have resulted only in the identification of a few additional types, such as the scapolite-amphibolite (regarding the mode of occurrence of which there is doubt, see p. 98), and the augite-camptonite, described by Thomson, from the Cavenagh Range.

A hypersthene-granulite has been found by Basedow in the Tomkinson Ranges, north of Mount Davis. From the description of the rock, it is identical with the garnetiferous hypersthene granulite from Cohn Hill. Moreover, as already stated, the bluish garnetiferous schists of the Mann Ranges are possibly also identical with this granulite.

From Streich's statement that two small outcrops of primary rocks occur ten miles east of Barrow Range as isolated hills of granulite, it is evident that he had discovered the granulites of Cohn Hill. His view, however, that they are part of the formation of the Townsend Ridges is erroneous, and is probably due to his confusing the foliation of the granulite with the true stratification of the sediments of the Townsend Ridge or Townsend Range series.

The considerable quantity of rhyolitic debris mentioned by Jack as being found in Tietkens Birthday Creek is, from the descriptions given, undoubtedly identical with the felsitic porphyries of the Warburton Range. Even the "flow" structure and the evidence of dynamic strain are similarly developed in the rocks from both localities.

Further, the sharply angular fragments of felspar porphyry found eighteen miles north-west of Mount Illbillie, is according to the description also identical with the felspar porphyries of the Warburton Range.

These two occurrences are very interesting, for, though the rocks were not found *in situ*, nor have acid porphyry dykes actually been seen east of the South Australian border, the angular nature of the felspar porphyry fragment from north of Mount Illbillie shows that it cannot have travelled far, and that therefore these dykes must outcrop somewhere in the vicinity, and are not confined to the area between the Warburton Range and Skirmish Hill.

The arbose collected by the Horne Expedition from Ayers Rock is undoubtedly very similar to the granitic arkose from Turban Hill in the Birksgate Range, which Streich regarded as a partially metamorphosed granite.

The pebbles of beautiful micro-pegmatite found in the conglomerate of Mount Olga are identical with the rock occurring *in situ* at Mount Squires. As Mount Olga consists apparently of conglomerate, the occurrence of pebbles of this peculiar rock which is known *in situ* only in the one locality, may ultimately prove to possess some significance from the point of view of the ancient geography of the region.

The quartzite from Mount Chandler is the same in all respects as that from the Townsend Ranges.

The outstanding differences between the Warburton District and the region to the east of it as far as the eastern extension of the Macdonnell Range, are the occurrence in the vicinity of the Warburton Range and to the south and east of it of vesicular dolerites and a conglomerate of volcanic origin, the very large development of felsitic quartz porphyry dykes, and the (probably) comparatively large development of greenstones, some of which are similar to those of the auriferous areas of the Western Australian Goldfields. Evidently, from the published reports, these latter rocks are conspicuously absent from the Central Region, at least as far as the eastern portion of the Macdonnell Range.

III.—CORRELATION OF THE ROCKS WITH THOSE FROM THE AURIFEROUS AREAS OF WESTERN AUSTRALIA.

Leaving out of account the pink granite and the acid porphyries, facies of which may be represented at Niagara in the Kookynie District,* the only rocks which admit of consideration in this connection are the greenstones. These have been found to occupy probably an area of about 400 square miles in the vicinity of the Warburton Range, and to contain quartz reefs. Though the assays which have been made from specimens from these reefs showed only a small content of gold ranging from grains to pennyweights per ton, there is no doubt that the greenstones are, in the main, remarkably similar to those occurring in the chief auriferous areas of Western Australia. The following are the chief types:—

Fine-grained fibrous zoisitic amphibolites.
Medium-grained dark-green amphibolites.
Coarse-grained greyish-green epidiorites or amphibolites very similar to lustre-mottled amphibolites.
Fine-grained, sheared, chloritised and epidotised epidiorites.
Fine-grained dark, greyish-green amphibolised ophitic dolerites in which the augite has been altered to fibrous hornblende.
Sheared fibrous chloritic, epidotic and zoisitic epidiorites.

Of these the coarse-grained amphibolites resembling the lustre-mottled rocks are practically identical with the lustre-mottled amphibolites from Kalgoorlie. The fine-grained altered epidiorites and amphibolites, and, in particular, the amphibolised ophitic dolerites and the chloritised and zoisitised uralitic epidiorites are exactly similar to the fine-grained amphibolites described in previous Bulletins from both Kalgoorlie and Meekatharra.

It is to be noted that the fine-grained amphibolites of Kalgoorlie and other localities are not generally payably auriferous; but in the most important cases—as at Kalgoorlie—they are associated with coarser greenstones which carry the auriferous formations.

Thomson † has described a rock resembling the rocks of the auriferous areas of Western Australia from the Cavenagh Range. He states:—

> The rock is a fine-grained amphibolite rather more felspathic than usual.
>
> Rocks very similar to this are of frequent occurrence in the goldfields of Western Australia, *e.g.*, Kalgoorlie, Norseman, the Murchison Valley, etc. They seem to form the country into which large dykes of coarse-grained basic rocks, now also amphibolites, have been intruded, and may therefore be termed the older amphibolites. As a rule these fine-grained amphibolites are not conspicuously auriferous, except at the contact of graphite ‡ or quartz porphyry. The specimen, however, is of considerable importance in showing that the rocks of the known auriferous belts are found as far eastwards as the Cavenagh Range.

In connection with this occurrence, it should, however, be remarked that the rock described by Thomson came from a collection made many years before he had the opportunity to examine it, and as Messrs. Talbot and Clarke's observations on the Cavenagh Range failed to discover such a rock, it is not improbable that with the lapse of time some confusion has arisen as to the exact locality from which the specimen described by Thomson actually came. On the other hand, the rock may be identical with that described (fig. 42) on page 97, as a thin dyke in the gabbro.

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* Pink granites and pink granular porphyries very similar to those occurring in the Warburton Area have been found near Niagara.

† *Loc. cit. ante.*

‡ Granite.

It is plain, then, so far as present knowledge goes, that whatever interest may in future be taken in prospecting in the Warburton District, it should be confined to the greenstone area mapped in the present Bulletin.

SECTION II.

DETAILED DESCRIPTIONS.

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I.—WARBURTON AREA.

A.—METAMORPHOSED ROCKS.

1. **Greenstones.**

$[\frac{1}{1137}]$ about 1¾ miles south-west of Mt. Waugh.

A very fine grained, dark greyish-black rock with small rounded and large irregular patches of a much lighter colour.

S.* The dark portions of the rock consist of a fine-grained mass of small green sometimes fibrous prisms or ragged plates of green partially chloritised hornblende, and small grains of quartz and clear felspar with intermixed grains and rods of zoisite, and some platy forms that may be pyroxene or zoisite, but which are too obscure to be made out in the section.

S.* = Description of Section.

Some undoubted pale-green diopside plates, however, do occur.

The lighter patches consist almost entirely of granular zoisite with granular quartz and felspar (albite), but contain in places greenish patches in which the green hornblende fibres are also to be seen.

No distinct igneous structure is determinable.

The rock is interpreted as a fine-grained fibrous, zoisitic amphibolite with yellowish patches, of which zoisite is the chief constituent to the exclusion of hornblende.

$[\frac{1}{1138}]$ about half-a-mile south-west of $[\frac{1}{1137}]$.

A fine-grained, dull-green rock, slightly porous in places, and with occasional whitish or yellowish angular patches resembling inclusions. There is a suggestion of shear structure.

S. In section, the rock is obscure both in structure and origin. It consists of numerous minute nearly colourless grains and granular aggregates of zoisite, with very small scales of greenish-yellow and brownish chlorite and chloritic biotite intermixed with small mosaic grains of quartz and felspar, the whole being nearly uniformly granular. Some platy calcite appears in some sections. The pale yellow angular patch visible in hand specimen is seen to consist of opaque grey zoisite with a comparative absence of chlorite, but with the small grains of quartz and felspar as in the surrounding mass. Except, therefore, for the absence of the greenish chlorite, there is little or no difference between the paler patches and the green mass, though the yellowish-green chloritic scales of the latter strike at the angular forms, and form a brownish border to them.

There is no defined structure in the rock, which it is impossible to name with accuracy.

It is a somewhat sheared chloritic zoisitic quartz-felspar rock, a product of advanced alteration of some undeterminable type, possibly a fine-grained dolerite or amphibolite.

$[\frac{1}{1070}]$ five miles N.N.E. of Camp 45, but locality doubtful (see p. 98).

A medium-grained, dark green, hornblende-felspar rock.

S. Consists chiefly of hornblende and felspar. The former is in large mostly irregular platy forms generally of a rather pale-green colour, but occasionally of a deeper green tint on the margins. The majority of the plates consist of an aggregate of small scales as if the original plates were in process of breaking down into smaller forms. There is, rarely, a tendency to a fibrous structure, and many of the plates are partially chloritised. The pleochroism is in yellowish to deep-green tones.

The hornblende encloses many rounded and angular crystals of black iron ore, some of which show a very thin border of a colourless mineral referred to epidote between them and the hornblende.

The felspar is rather less common than the hornblende, and occurs in fairly large plates and columns showing both albite and pericline lamellation. The crystals are slightly kaolinised and micacised, and enclose sometimes zoisite and hornblende grains, sometimes an unusual colourless mineral. The latter is in irregular small plates in the felspar, in thin strings along the cleavage traces, or in small granular aggregates. It has an index of refraction slightly above that of quartz, a birefringence somewhat greater than that of quartz, a fairly definite cleavage with straight extinction along traces, a uniaxial interference figure that is negative in sign. The mineral in most cases appears to be replacing lime-soda felspar. From these characters it is to be referred to scapolite, which though occurring elsewhere as an alteration of the lime-soda felspar of gabbro or amphibolite, has not hitherto been noted from Western Australia. Some of the felspar crystals are enclosed by hornblende, or have hornblende moulded on them. There is a considerable development of apatite in the rock, in rather long and thick colourless needles.

The structure of the rock is rather gabbroid than ophitic. There are deformation effects such as irregular extinction and lamellation, and banding of twinning planes in the felspar, and partial granulation of both felspar and hornblende.

The rock is a coarse-grained scapolite amphibolite, probably derived from a gabbro by atleration of the augite to green hornblende.

[$\frac{1}{1049}$] half-a-mile south of Camp 42.

A coarse-grained, greyish-green hornblendic rock, not unlike a lustre-mottled amphibolite, but much lighter in colour. There are frequent large green hornblende crystals, with a tendency to lustre-mottling.

S. Consists in places of large ragged more or less fibrous (particularly at the margins) plates of nearly colourless hornblende and occasional fragments doubtfully referred to original colourless augite, small scaly aggregates and patches of nearly isotropic chlorite, and large crystals of leucoxene derived from ilmenite. In other places, there is a fine granular mass of epidote grains, zoisite grains, chlorite scales and patches, albite grains and quartz grains. The zoisite and, in part at least, the epidote have been derived from pre-existing felspar of which, however, in the section, few definite traces remain. The zoisitic granular mass occurs also between the large ragged hornblende plates. The structure of the rock is not distinct, but in places an ophitic relation is observed between a large hornblende plate and a columnar form that is now largely composed of zoisite grains.

Orthopinacoidal twinning is noticeable in the large hornblendes. The large plates are in course of disintegration, and are often punctuated by nests of chlorite scales.

Epidote, zoisite and leucoxene are strongly developed.

The rock is a coarse-grained fibrous highly zoisitised and epidotised epidiorite, doubtless derived from a coarse-grained gabbro.

[$\frac{1}{1083}$] Just north of Mt. Weir (one of a suite of specimens illustrating various phases of the Greenstones).

A dark-yellowish-green, fine-grained, considerably sheared rock, the yellowish tint being due to minute spots among green chlorite.

S. Much decomposed. Consists of a dense mass of small green chlorite flakes and numerous chlorite scales, and aggregates of epidote and zoisite as well as numerous small grains of these, with some small round quartz crystals and fine granular quartz and albite grains. Only rarely can any trace of the original felspar be seen, and then it is too small and altered for identification. From the amount of zoisitisation and epidotisation, however, the species must have been fairly basic.

Original structure is completely obliterated, though results of the shearing are seen in the tendency to parallelism of the chlorite flakes.

The rock is a fine-grained, sheared, chloritised, zoisitised and epidotised epidiorite, much decomposed.

[$\frac{1}{1046}$] near Miller Hill.

A dense pistachio-green mass of epidote needles and grains with large areas of irregular quartz-plates and in some cases of quartz and kaolinised felspar plates. The reticulation of epidote needles produces an effect very similar to that produced by the interlacing of felspar laths or thin prisms in fine-grained basaltic dolerites.

[$\frac{1}{1044}$] near Miller Hill.

A fine-grained rather dark greyish-green rock resembling the fine-grained amphibolite from Kalgoorlie.

S. Rock evidently much decomposed. Consists of an indistinct loose plexus of long thin columns of felspar that in places have been altered to a fine-grained opaque granular mass of zoisite grains, in places have been altered to or have been replaced by green chlorite scales. Between the columns are indistinct pale nearly colourless fibrous ragged plates of hornblende, that appear dusty and grey owing to the association with them of minute grains of zoisite.

Broadly, the rock consists of a plexus of chloritised and zoisitised felspar columns or laths with indistinct ragged fibrous plates of hornblende obscured by fine granular zoisite and green chlorite scales. A little interstitial quartz in small plates is observable. In places there are clearer areas composed of a mass of epidote and zoisite grains, quartz grains and calcite grains surrounding a patch of bright green isotropic chlorite. Some small fragments of leucoxene are scattered over the slide.

The slide is of low birefringence owing to decomposition. The structure is indicative of a former ophitic relation between the felspar columns and the original of the hornblende plates.

The rock is now a much weathered, zoisitised and chloritised ophitic dolerite, in which the augite has been altered to fibrous hornblende or to chlorite. The sections bear a close resemblance to [11318] from Meekatharra and the fine-grained amphibolites from Kalgoorlie.

[$\frac{1}{1123}$] near Mt. Herbert.

A fine-grained, yellowish-green, somewhat sheared rock, with small spots of epidotic material.

S. The rock is somewhat obscure in section owing to both chemical and dynamic alteration. It consists largely of grains and granular aggregates of yellowish epidote and ragged pale-green more or less fibrous plates or columns of hornblende and chloritised hornblende, with very indistinct traces of original columnar felspars that are now wholly zoisitised and epidotised. The hornblendic plates are often intensely fibrous, ragged and interrupted, and are usually considerably bent or contorted. Some isotropic green chlorite occurs in small patches in addition to the chloritic hornblende. Besides the epidote and zoisite developed at the expense of the felspar, there are small plates of quartz, some granular calcite, and fine granular albite. Leucoxene was observed in granular form in various parts of the section. Ophitic structure has been almost wholly obliterated. The rock in structure and composition bears some resemblance to the fine-grained zoisitic amphibolites of Meekatharra.

The rock is a sheared epidotised, zoisitised and amphibolised dolerite. In its present condition it is perhaps best designated a fibrous chloritic, epidotic and zoisitic amphibolite or epidiorite

[$\frac{1}{1118}$] Frank Scott Hill.

A greyish-green medium-grained rock, showing some columnar and small platy greenish felspar.

S. Proves to be a much altered, zoisitised, chloritised, uralitic epidiorite, such as is common in Kalgoorlie and Meekatharra. There are large zoisitised and kaolinised columnar crystals of basic felspar in more or less distinct ophitic relation with ragged plates of ferro-magnesian that is in part nearly colourless fibrous hornblende, in part that mineral altered to chlorite. In most cases, the fibrous forms show distinct remains of the original augite, and ragged plates of unaltered augite also occur to some extent. Grains of epidote occur with the chlorite, and some ragged plates of leucoxene are visible.

The rock is a much altered chloritised and zoisitised uralitic epidiorite with original augite.

2. Acid Plutonic and Dyke-rocks.

(a.) Granites, Gneisses and Granular Porphyries.

(i.) *Pink Granites, Gneisses and Granular Porphyries.*

[$\frac{1}{1061}$] Hill about seven miles south-west of Camp 43.

A minutely-grained, felsitic, dark-grey flinty rock, weathering on the surface to a dirty yellowish-white. Very rarely a reflecting surface of a felspar crystal is visible.

S. Consists of a micro-crystalline mass of quartz and felspar with occasional slightly larger quartz plates and quartz aggregates. Small scales of green chlorite, grains of magnetite, small scales of muscovite, and a rare, reddish-violet crystal, apparently of a garnet, are visible.

Rock a felsitic quartz-porphyry without phenocrysts.

[$\frac{1}{1068}$] about 5½ miles south-west of Camp 44.

Identical essentially with [$\frac{1}{1136}$] but darker in colour and with very little garnet present.

[$\frac{1}{1136}$] 3½ miles north of Mt. Waugh.

A very fine-grained, pinkish-grey, felsitic rock, with rare small reflecting surfaces of felspar.

S. Consists of a fine-grained granular mass of quartz and felspar plates about equal in development, enclosing small grains of pink garnet, black iron ore, green chlorite scales, brown biotite scales, and white muscovite scales, epidote grains and occasional small flakes of partially chloritised green hornblende. The felspar plates are partly fresh, partly slightly kaolinised, and some are untwinned, some twinned on the albite law. A few felspar plates have a suspicion of the grating structure of microcline. Some plates of quartz and felspar occur larger than the rest of the minerals, but not idiomorphic.

Rock a granular quartz-porphyry without phenocrysts.

[$\frac{1}{1064}$] "Spring Granite" (Camp 43).

A medium-grained, pinkish, granitic rock, with distinct incipient foliation, shown especially by the stretching out of the quartz plates into lenticles all in the same direction.

S. Consists of some large irregular platy crystals of quartz and felspar partially disintegrated and separated by a finer-grained granular mass of quartz and felspar plates and grains, which are the product of granulation of larger plates. The felspar is in part microcline, in part orthoclase. In many cases a partial, fine polysynthetic lamellation has been developed in felspar grains, probably the result of the granulating stress, especially as the lamellation is sometimes curved. Rarely there is an occurrence of an intergrowth of two felspars resembling that commonly occurring with microcline and albite. Effects of dynamic stress are pronounced and are shown by irregular extinction in both quartz and felspar, irregular twinning, partial granulation of plates, and the occurrence in places of whole areas of a fine granular mosaic of quartz and felspar. Some grains of iron ore (ilmenite) and greyish white material, possibly leucoxene, are occasionally to be observed.

The rock is a highly granulated, considerably mechanically deformed and partially foliated microcline-granite.

[$\frac{1}{1066}$] 1¾ miles north-east of Camp 43.

Very coarse-grained and pink as before, with large pinkish felspar crystals and aggregates of black biotite scales.

S. Consists chiefly of platy and tabular crystals of felspar all slightly kaolinised, and large platy crystals of clear quartz, with loose aggregates of ragged brown-yellow biotite scales and rarely a plate of brown-yellow or greenish-brown hornblende. The felspar is chiefly microcline with the characteristic gridiron structure, and though in some cases this structure may be the result of dynamic stress on the rock, its prevalence and irregularity point to its being of primary origin. Some apparent orthoclase and an acid plagioclase about oligoclase also appear.

There is a tendency for some of the felspar to assume a rounded granular shape, and inclusions of the rounded grains, most of which appear to be the acid plagioclase, occur in some of the microcline plates.

Hornblende is much less common than biotite, in fact its occurrence is only occasional.

Some black iron ore and some other minor occurrences, *e.g.*, epidote grains were identified.

There is marked evidence of strain in the rock, shown by irregular extinction in the quartz and felspar and irregular lamellation in the felspar.

The rock is a biotite-hornblende-microcline granite.

[$\frac{1}{1132}$] Gnamma Hole about 3¼ miles W.S.W. of Camp 68.

A reddish, coarse-grained, granitic rock, with a comparative absence of ferro-magnesians, but with small fine grains of partially altered iron ore (ilmenite).

S. In section the rock consists of large partially granulated plates of microcline, orthoclase, and ragged plates of quartz, with patches of fine granular mosaic of quartz and felspar, grains of iron ore, a few scales of muscovite, needles of rutile, rare scales of chlorite, etc. In some places a very coarse intergrowth of quartz and felspar is visible. Uneven extinction in quartz and felspar, bending of the lamellæ as well as slight development of secondary twinning, and the partial granulation of quartz and felspar plates, bear witness to the action of dynamic stress on the rock.

[$\frac{1}{1067}$] near Camp 44.

A fine-grained, dark, pinkish-grey, granular rock, with small reflecting surfaces of felspar.

S. Consists of a fine-grained platy and granular mass of felspar and quartz, with a few small grains of green hornblende and green chlorite as well as small grains of magnesite and apparently of sphene. (Fig. 48.)

Fig. 48.

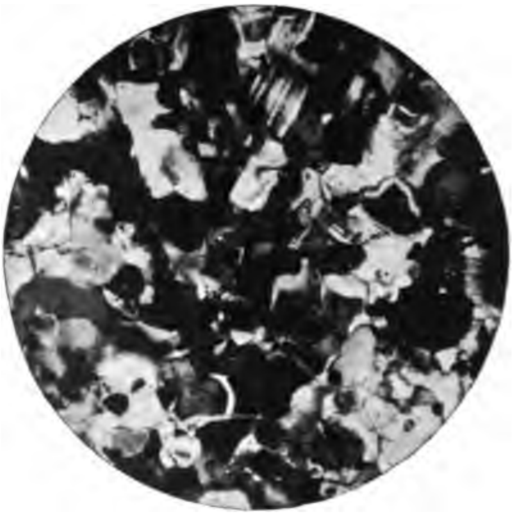

Photo.: R. A. Farquharson. Neg. 1620.

[$\frac{1}{1067}$] **The granular porphyry showing the fine-grained platy granular structure of the rock.**

Some larger platy forms and platy aggregates of felspar occur. The felspar species are in part orthoclase, in part an acid plagioclase, and many of the plates show an imperfect development of the cross-hatching of microcline, a feature, however, which may be a strain phenomenon. Irregular extinction is noticeable in both quartz and felspar. No phenocrysts are visible, and no mica.

The rock is a fine-grained, platy, granular felspar-quartz rock, probably a granular facies of a quartz-porphyry.

[$\frac{1}{1133}$] Bentley Hill.

A pale pinkish-grey, fine-grained, granitic rock, with small streaks and patches of a rather black biotitic mineral.

S. Consists of large ragged plates of microcline highly kaolinised and partially granulated, large ragged plates of quartz, also partially granulated, and some strings, and small grains and scales of brown biotite, green chlorite and rarely green hornblende with a little zoisite, and yellow epidote in grains. A few small plates of an acid plagioclase also appear, sometimes enclosed in the microcline. Between the large plates are areas of a granular mixture of quartz and felspar, obviously the result of partial breaking down of the larger plates through dynamic agencies. Uneven extinction in both quartz and felspar and irregular lamellation in the felspar as well as cracks in both minerals are common. Grains of iron ore—ilmenite, and some greyish material round the iron ore which is referred to leucoxene—are rather plentiful.

The rock is a microcline-biotite-hornblende granite partially granulated.

$[\frac{1}{1134}]$ about seven miles south of Camp 69 (Bentley Hill).

Similar to $[\frac{1}{1132}]$ but not so coarsely grained.

S. Essentially similar to $[\frac{1}{1091}]$; microcline is not so distinct as in $[\frac{1}{1066}]$, and orthoclase appears to be more common, but the rock is undoubtedly genetically connected with the above.

(ii.) *Grey Granites and Gneisses.*

$[\frac{1}{1097}]$ Lightning Rock.

A coarse-grained granitic rock.

S. Consists almost wholly of plates of microcline and quartz with occasional columnar crystals of a striped plagioclase and flakes of brown biotite. There is marked evidence of dynamic strain in the irregular extinction of the quartz and felspar, the presence of secondary lamellation in the felspar, but chiefly in the partial—in some cases nearly complete—granulation of the quartz and felspar plates. The striped plagioclase is in all cases highly decomposed with the production of granular or fine acicular zoisite or of kaolin, and the columns are not infrequently enclosed in the microcline plates. Small thin needles of rutile are observable, probably due to the alteration of biotite.

The rock is a coarse-grained microcline-biotite granite with marked effects of dynamic strain shown in partial granulation and optical irregularities.

$[\frac{1}{1116}]$ About one mile east of Mt. Scott.

A very coarse-grained grey granite with occasional small black patches.

S. Consists of irregular platy crystals of felspar and quartz—the former in excess of the latter—with patches of ragged, more or less decomposed, green pleochroic hornblende plates, a few flakes of brownish biotite and some granular iron ore. The species of felspar appear to be chiefly orthoclase and microcline. The most noteworthy feature of the sections is the enormous amount of mechanical deformation they show. All the crystals of the felspar and quartz are remarkably strained; irregular extinction, secondary lamellation, crushing, cracking and partial granulation of both quartz and felspar are all most pronounced. The deformation seems to have occurred along more or less well-defined shear zones, but the whole rock has been affected by it. (Fig. 49.)

There are occasional quartz inclusions in the microcline plates, and a few small areas of a micro-pegmatite resembling those in [$\frac{1}{1117}$] A few accessories, such as apatite needles, etc., are also present.

The rock is an extremely crushed microcline-hornblende-biotite granite.

Fig. 49.

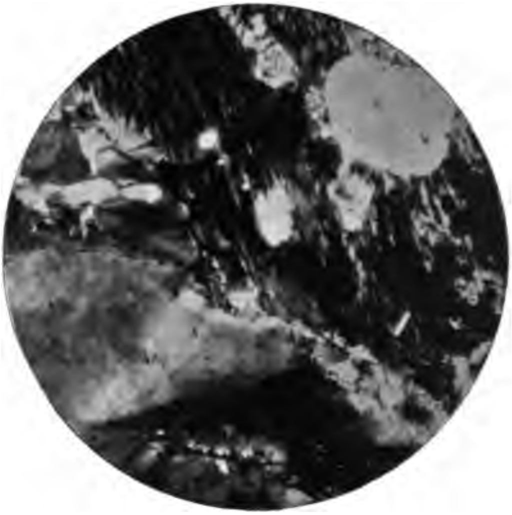

Photo: R. A. Farquharson. Neg. 1621.

[$\frac{1}{1116}$] The biotite-microcline granite illustrating the extreme stress.

[$\frac{1}{1117}$] Mt. Scott.

A rather fine-grained dark grey granitic rock composed of biotite, quartz and felspar.

S. The section consists of numerous large ragged plates of felspar and fewer and smaller plates of quartz, with a considerable development of biotite in ragged brown-yellow strings of pleochroic flakes. The felspar in some cases shows no twinning, in others indistinct albite lamellation, in others pericline striation, and not infrequently a partial development of the cross-hatching of microcline. As there are decided evidences of dynamic strain in the rock, this partial cross-hatching may be the result of pressure, and not an original structure or at least not originally developed to the present extent. The species of felspar appear to be in part orthoclase and microcline, in part a plagioclase. All the plates are more or less kaolinised and most are partially micacised.

The quartz occurs in small plates and grains, is in much smaller development than the felspar, and in some cases appears almost interstitial. Undoubted inclusions of squarish quartz grains, however, are observable in the felspar. The biotite flakes are very common, and are occasionally intermixed with small scales of muscovite.

In some places there occur small areas of an intergrowth of quartz and felspar, generally on a rather minute scale, but rarely rather coarse.

In a few instances, this intergrowth resembles the "myrmekite" of Sederholm. There are thin quartz rods more or less parallel in felspar, and these areas occur between large plates of orthoclase or microcline and a plagioclase. It is probable, however, from the occurrence in other parts of the slide of rather coarse normal intergrowths of quartz and felspar, that these small areas are rather merely vermicular micropegmatite.

There is marked evidence of dynamic strain in the rock. The felspars show uneven extinction, bending of the lamellæ secondary lamellation and partial granulation, while cracks are common both in the felspar and in the quartz. A few grains of sphene are observable.

The rock is a biotite-microcline granite of rather fine grain, probably a finer-grained variety of [$\frac{1}{1116}$].

[$\frac{1}{1104}$] Camp 55 (Barnard Rocks).

A medium-grained pinkish-grey granitic rock with many small patches of blackish biotite.

S. Consists of large plates of orthoclase and microcline and ragged plates of quartz with a few flakes of brown biotite. Both quartz and felspar show strain shadows, uneven extinction and cracks, and the felspar in places has a secondary lamellation. Other marked evidence of dynamic strain is shown in granulation of quartz and felspar plates, some of the former showing bands of granulated quartz through the quartz plates. A plagioclase in small crystals appears to be enclosed in places in the microcline. The felspar is kaolinised, zoisitised and micacised in different cases.

Quartz plates are especially granulated in places.

The rock is a biotite-microcline granite, very similar to [$\frac{1}{1115}$].

[$\frac{1}{1108}$] Hills about four miles W.S.W. of Camp 57.

A medium-grained, grey, granitic rock, consisting chiefly of platy felspar and resembling [$\frac{1}{1115}$], but much finer in grain, and with less of the chloritic material.

S. Consists of platy irregular crystals of felspar and few of quartz with a few scales of brown biotite.

The structure is distinctly granitic. There is, however, slight granulation of the quartz and felspar at the margins, irregular extinction of both quartz and felspar due to strain, cracks, and a suspicion of schiller in the felspar, and some secondary lamellation, due also to strain. The species of felspar is in part orthoclase or microcline, in part an acid plagioclase.

A bending of the flakes of biotite is occasionally observable.

Some vermicular intergrowths on a small scale are not uncommon; there is a little magnetite, in large grains; and the felspars are all slightly kaolinised. Quartz is markedly less developed than the felspar, and only in relatively small plates.

The rock is a highly felspathic biotite granite with quartz in relatively small amount.

[$\frac{1}{1113}$] Amy Giles Rocks.

A coarse-grained granitic rock very similar in appearance to [$\frac{1}{1115}$], but rather finer in grain, without chloritic patches and with quartz showing a violet or heliotrope tint, and fairly common.

S. Consists of allotriomorphic plates of partially kaolinised felspar and clear quartz with a rare flake of brown biotite and green-yellow hornblende crystals and with the margins of the quartz, and to a small degree the felspar slightly granulated. Some of the felspar plates are of columnar and tabular form, but most are irregular in shape. Uneven extinction is common but not very pronounced in both the quartz and the felspar. The felspar species appears to be in part orthoclase or microcline, in part a finely lamellated acid plagioclase, and all forms are more or less turbid from kaolinisation. In some cases a rod-like or vermicular intergrowth appears in a felspar plate. Rarely a square columnar crystal of felspar is enclosed in a large plate of quartz.

It differs from [$\frac{1}{1118}$] in the absence of pink garnet, and in the small development of interstitial granulitisation, and in the paucity of ferro-magnesians.

The rock is a highly felspathic biotite-hornblende granite with fairly well-marked dynamic strain effects.

[$\frac{1}{1115}$] Camp 59 (near Mt. Gosse).

A very coarse-grained greyish granitic rock with very large tabular and platy crystals and much smaller quartz crystals, as well as small black patches with the quartz and felspar.

S. Consists of very large platy crystals of untwinned but slightly schillerised and slightly kaolinised felspar with few ragged plates of clear quartz, separated by a fine granular mass in places of felspar, in places of quartz in which are aggregates of granular pink garnet, frequently with associated brown-red biotite and small green scales of chlorite that appear to have been derived from hornblende. A few small highly refracting rods also with the garnet are referred to zircon. (Fig. 50.)

Fig. 50.

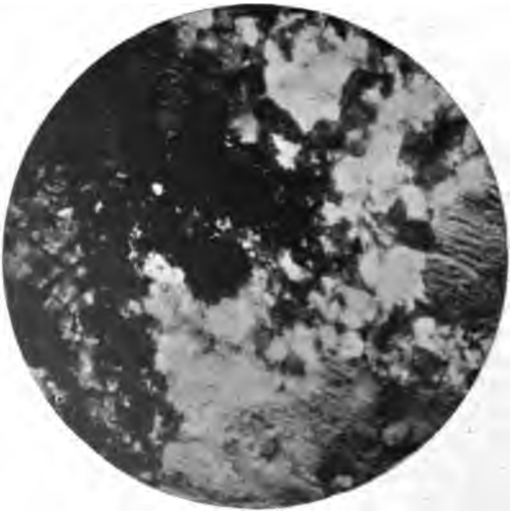

Photo: R. A. Farquharson. Neg. 1622.

[$\frac{1}{1115}$] **The grey gneissic granite with granular garnet and partial granulitic structure.**

The noteworthy feature of the slides is the fact that the fine granular mass both of quartz and felspar has obviously been derived from the granulitisation of the felspar, and in part of the quartz plates by some dynamic stress. The large felspar plates are generally cracked and highly granulitised along the cracks, so that portions of the same plate are separated by a band of the granulitic mass. The margins of both the quartz and felspar plates are extremely irregular, due to the breaking of the crystal outlines and formation of the granular mosaic. Schiller structure is finely developed in many of the larger felspar crystals, and uneven extinction is most marked both in the felspar and the quartz. In some of the large felspar plates are many very small rod-like forms all with more or less parallel alignment, and all extinguishing together. They appear to be an intergrowth in the felspar, and since some appear to be turbid from kaolinisation they are referable probably to albite. Minute intergrowths of small dots occur, and some minute indistinct rods probably representing another intergrowth. Dynamic stress has developed almost a fine fibrous structure in some fragments of the felspar.

Some grains of black magnetite are not uncommon.

The structure of the rock is decidedly granitic, but the rock has been severely crushed.

The species of felspar was difficult to make out, but the absence of albite lamellation and of any twinning, together with the peculiar fibrous character of some of the plates suggests orthoclase or microcline as the chief species.

There is no distinct banding in the rock, but since, from field evidence of the mass of the rock, a pronounced banding is observable in the country, the rock is put down as a partially crushed garnetiferous granitic gneiss or gneissic granite.

$[\frac{1}{1095}]$ Cohn Hill.

A fine-grained, dark bluish-green, apparently silicious rock with numerous small rounded crystals of red garnet. A rough, imperfect foliation is present, but indistinct.

S. Minerals: garnet, hypersthene, quartz, felspar, biotite, iron ores, spinel (?), zircon.

In ordinary light the sections consist of numerous large rounded and angular crystals of pink garnet, irregular grains of black iron ore, small grains and aggregates of grains, and rarely small ragged prisms of a mineral highly pleochroic in red and green tones, scales and small scaly aggregates and strings of brown biotite, all in a clear colourless mass of felspar and quartz.

The garnets occur in large rounded and angular crystals of a pink colour, occasionally with one or more crystal edges, and rarely with inclusions of small scales of brown biotite, grains of quartz and granules of zircon, the latter in some cases with pleochroic halos. In general, however, the mineral is singularly free from inclusions. Optical anomalies are rare, though slight double refraction is visible in some of the forms.

The highly pleochroic grains are especially noteworthy. In no case do they show any crystal outlines, cleavage is rarely visible, but in those cases where it can be made out, it is perfect and prismatic. Very rarely grains are observable which show two sets of cleavage traces practically at right angles to one another.

The mineral has generally straight extinction parallel to the cleavage traces. The pleochroism is quite strong, in tones from reddish brown to deep bluish or emerald green. From these characters, together with the high refractive index and biaxial character, the mineral is referable to the rhombic pyroxene, hypersthene. A peculiar feature of a few of the grains is that the extinction on the (somewhat doubtful) cleavage traces does not appear to be straight, but very considerably inclined, a circumstance which suggests the presence of a monoclinic pyroxene with the pleochroism of hypersthene. Owing, however, to the smallness of the grains and to the indistinctness of the cleavage traces, observation of the extinctions in these grains is difficult, and it is possible that the monoclinic character is only apparent. Rarely, however, there may be observed a grain which is pale green in colour and not pleochroic, and which may be referred to augite.

The quartz-felspar mass forms the bulk of the rock, and quartz is apparently much in excess of the felspar. The mass consists of angular ragged and rounded plates of quartz and felspar in a fine granulated or indistinctly granulitic mass produced by the breaking down of quartz and felspar plates. The larger quartz plates have a distinct elongated shape and a linear arrangement as if drawn out in parallel direction. They are all cracked, broken, and partially granulitised, and all show more or less irregular extinction as well as rows of fluid pores. The felspar plates are also in angular and irregular shapes, they frequently show minute partial lamellation, bending of the lamellae, uneven extinction and partial granulation, effects due undoubtedly to severe strain. The species present are acid, but difficult to determine. Orthoclase, however, and an acid plagioclase are apparently commonest. No definite microcline plates were observed.

Fig. 51.

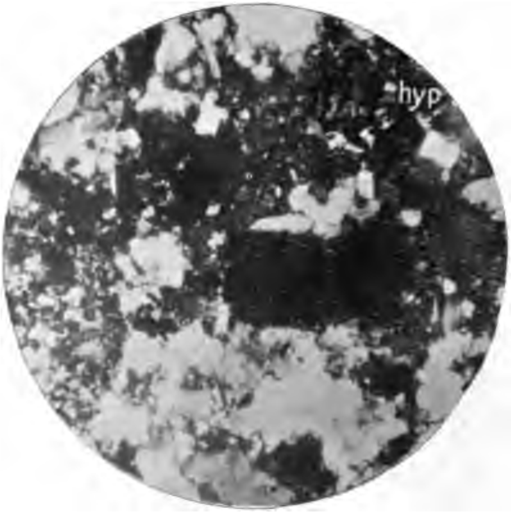

Photo: R. A. Farquharson. Neg. 1623.

[$\frac{1}{1095}$] **The pyroxene granulite, with granular hypersthene, garnet, and a granulitic structure.**

The biotite scales are in all cases very small, brownish-yellow or brown in colour, and in loose aggregates or thin strings.

The iron ore, which is apparently chiefly magnetite, is remarkable for the fact that associated with it are sometimes small grains of a dark-green isotropic mineral, blackish by incident light, which is perhaps referable to a spinel, pleonaste or hercynite.

A few grains of zircon occur in the rock mass as well as in the garnets. No graphite and no sillimanite or other metamorphic minerals were observed.

The structure of the rock is essentially granular, the result of granulation or granulitisation of the colourless constituents and of the occurrence of the pyroxene in granular forms. There is a tendency to foliation noticeable in the disposition of the lenticular plates of quartz, and to a small extent in the arrangement of the biotite strings. (Fig. 51.)

The rock is, therefore, a garnetiferous-hypersthene gneiss or granulite.

The amount of material available is too small to allow of a chemical analysis being made of the rock, but from the composition and the structure, it would appear that the rock-mass was originally of granitic character. Moreover, there is undoubted resemblance between this hypersthene-granulite or gneiss and some of the acid varieties in the charnockite series described by Dr. Holland from South India, and in particular to the varieties that have been dynamically metamorphosed, with the production of garnets and a gneissose structure. This resemblance has already been described.

[$\frac{1}{1111}$] Cairn on Mt. Aloysius.

A dark greyish or yellowish-brown rock with indistinct reddish garnets without crystal faces, some quartz, and small thin columnar or acicular crystals, well-cleaved and with adamantine lustre. In the weathered surfaces they are seen to be sometimes in small bundles.

S. Consists of large irregular plates and grains of nearly colourless or faintly pink garnet without any crystal faces, small rods, prisms and prismatic aggregates of a colourless mineral of high refractive index, and some yellow-stained grains and plates of a mineral with small refractive index, all interspersed with irregular plates of quartz.

The garnets are irregular in outline, and often enclose grains of black iron ore (magnetite). In one instance a remarkable feature was noticed in connection with the mineral, viz., the inclusion of a grain of a green spinel. Inclusions of quartz grains and abnormal birefringence are not uncommon.

The prismatic mineral of high refractive index—which is the mineral with adamantine lustre visible in hand specimens of the rock—proves to have the following characters : prismatic forms with a perfect longitudinal cleavage, straight extinction, a marked cross-jointing, a birefringence that is moderately strong and considerably higher than that of quartz, and a refractive index almost that of zoisite, *i.e.*, about 1.70. Basal sections of the prisms are stout, rectangular, or squarish in form, the birefringence is positive, the elongation is positive, and the optic axial angle is very small, so small in some sections that the figure is nearly uniaxial. The axial plane is parallel to the brachypinacoid, and the acute bisectrix is at right angles to the vertical axis. A little of the mineral powder as pure as could be obtained gave a blue colour on ignition on charcoal with cobalt nitrate. From these characters there *is little doubt* that the mineral is referable to sillimanite. In many respects the mineral resembles cyanite, but the small axial angle amongst other characters rules out the latter. Thomson,* in his examination of a rock occurring in small hills East of the Barrow Range, found, but did not identify what is apparently the same mineral.

The dusky platy mineral of low refractive index resembles quartz, but owing to its apparent—though indistinct—biaxial character where obtainable, is probably referable to cordierite. The quartz is in irregular coarse platy forms which show marked effects of dynamic strain, such as partial or complete granulation, cracks and great irregularity in extinction.

The rock is a dynamically strained garnetiferous-sillimanite-quartz rock of granulitic character.

$[\frac{1}{1112}]$ about 1½ miles west-south-west from Mt. Aloysius Cairn. Rock outcropping in watercourses.

A fine-grained white felspathic rock with faint suggestion of foliation, heavily charged with small dark-red garnets and with small crystals of clear quartz visible in places.

S. Sections appear indistinctly banded. There appear to be bands of fine kaolinised felspar and quartz separated by highly quartzose bands in which the quartz occurs in elongated ragged strips, which are remains of larger quartz plates partially granulitised. Granular felspar also occurs in these bands. Here and there in the slide are ragged imperfectly lamellated kaolinised plates of felspar which appear to be remains of phenocrysts. They are generally granulated at the margins. Irregular extinction is very pronounced both in the quartz and in the felspar, and irregular lamellation is common in the felspars. There is a strong development of faint-pink garnets in large and small rounded forms, enclosing quartz grains.

The original structure is not clear, but appears to have been either coarse platy or felspathic with felspar phenocrysts.

The rock is a highly garnetiferous granitic quartz-felspar rock—granite-porphyry or granite—now in course of alteration to a garnetiferous granitic gneiss.

$[\frac{1}{1114}]$ 7½ miles west of Camp 59.

A fine-grained grey foliated granitic rock.

S. A fine-grained foliated garnetiferous quartz-felspar gneiss, with marked evidence of mechanical or dynamic deformation in fracturing of quartz and felspar, development of a rude foliation, uneven extinction in both quartz and felspar. Granular sphene present and some smaller scales of chloritic biotite. Felspar is in part orthoclase, in part microcline, though the microcline structure may be in part due to dynamic stress. Incipient thin bands of quartz present. There are crystals of the same acicular prismatic mineral as in $[\frac{1}{1111}]$

Rock is a foliated garnetiferous-sillimanite gneiss, containing quartz and felspar.

(b.) Porphyry Dyke Rocks, usually little metamorphosed.

(i.) *Eveline Dyke*—

$[\frac{1}{1082}]$ Cairn on Mt. Eveline.

A finely porphyritic dark-grey rock consisting of numerous pinkish phenocrysts of felspar and smaller rounded phenocrysts of quartz in a felsitic ground-mass.

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* Thomson. Rock specimens from Central and Western Australia. Journal and Proc. Roy. Soc., N.S.W., Vol. x.

S. Consists of large, slightly rounded, tabular and irregular phenocrysts of felspar, and large rounded phenocrysts of clear quartz in a micro-crystalline ground-mass of quartz and felspar grains, obscured by numerous yellowish-green chloritic scales and small grains of iron ore. (Fig. 52.) The felspar phenocrysts consist chiefly of a finely striped plagioclase of acid species, but obscured by kaolinisation. Some untwinned forms may be orthoclase. From the turbidity and unevenness of the extinction in the forms, the species was not ascertained with certainty. The felspar phenocrysts frequently have very irregular shape, and appear to have suffered from resorption to some extent. The quartz phenocrysts show enlargement by the ground-mass and also in some cases resorption. Chlorite scales are common in the ground-mass, and greenish-yellow and green chloritic aggregates occur in places, while some epidote grains were observed. Rarely some greenish forms with the cleavage of hornblende occur, and it is probable that the chlorite is derived from original hornblende in the rock. Some quartz-muscovite-chlorite aggregates occur, probably as alteration products.

Fig. 52.

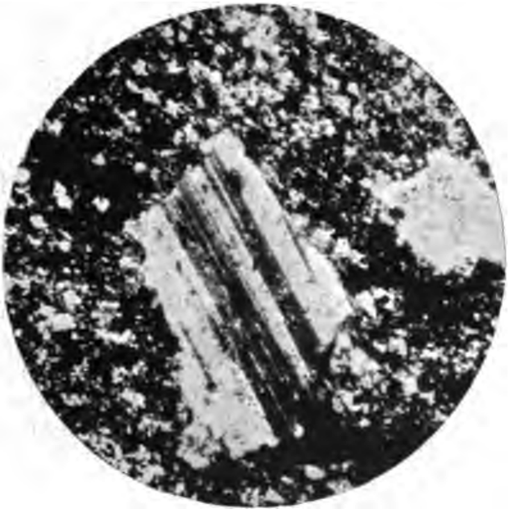

Photo: R. A. Farquharson. Neg. 1624.

[$\frac{A}{1082}$] **Felsitic quartz porphyry with phenocrysts of felspar and quartz.**

A noticeable feature of the slide is that the chloritic scales have a distinct parallel alignment, and sweep around the felspar and quartz phenocrysts in places. This feature, however, seems to be due rather to mechanical strain on the rock than to an original "flow" structure.

The rock is a chloritic quartz-porphyry, finely porphyritic with felsitic ground-mass.

[$\frac{1}{1140}$] Kathleen Hill.

A very fine-grained, felsitic, dark-grey rock with a few small phenocrysts of quartz showing. A sheared structure noticeable. Quartz in part, pale blue.

S. Consists of a rare quartz phenocryst in a fine-grained ground-mass of which portion is micro-crystalline or crypto-crystalline, and portions are coarser and fine platy form. In the ground are patches of coarse quartzose mosaic apparently due to the breaking down of larger quartz plates. There is a fine dust all over the slides, which consists in part of fine granular iron ore. Numerous very small grains of pink garnet and occasional flakes of muscovite occur in the ground.

The rock is a fine-grained garnetiferous quartz-porphyry with some phenocrysts of quartz.

[$\frac{1}{1053}$] about 2½ miles north of Camp 42.

A greyish-white, fine-grained, finely porphyritic rock with small phenocrysts of clear quartz and less obvious and smaller phenocrysts of felspar, and a reddish weathered crust. Small grains of pyrites are scattered through the mass of the rock.

S. Consists of ragged rounded partially resorbed phenocrysts of clear quartz in a crystalline ground-mass composed of a little quartz in small plates, and much felspar in ragged plates and many varieties of curved, feathery, tufted, wavy and divergent forms which are probably intergrowths. Many show a distinct approach to a radial form and hence to a spherulitic appearance, but no true spherulites or pseudo-spherulities were observed. (Fig. 53.)

Fig. 53.

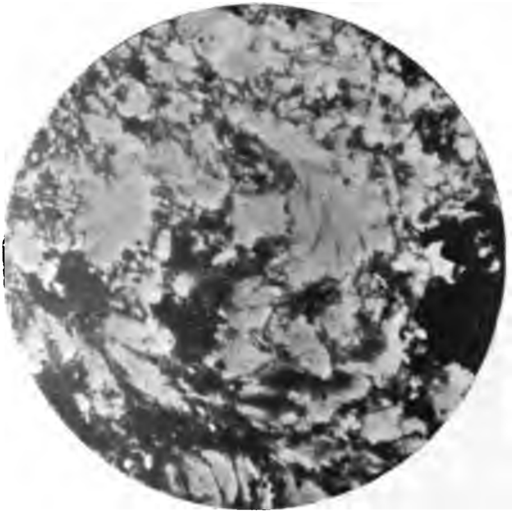

Photo: R. A. Farquharson. Neg. 1625.

[$\frac{1}{1053}$] **Quartz porphyry with peculiar curved, divergent and radial felspar.**

Very rarely a large partially micacised phenocryst of felspar is noticeable with indistinct lamellation.

A certain amount of mechanical deformation is noticeable in the slide, evidenced by the irregularity of extinction of the quartz, and the irregularity of lamellation and extinction in the felspar. Some chlorite scales, and pyrite grains are present.

The rock is again a quartz-porphyry with quartz and felspar phenocrysts and an approach to a granophyric structure.

$[\frac{1}{1054}]$ about five chains north of specimen $[\frac{1}{1053}]$.

Similar in appearance to $[\frac{1}{1084}]$, but with pale blue quartz phenocrysts.

S. Consists of occasional large ragged platy and tabular phenocrysts of felspar and rare phenocrysts of quartz in a fine-grained groundmass of streaky appearance, due to the fact that some portions are micro-crystalline, and others are coarser in grain. In general, the mass is composed of quartz and felspar, but the coarser portions consist largely of quartz plates. A noteworthy feature of the slides is the fact that there is a parallelism of the streaks, and in some cases there is a "flow" structure noticeable round the phenocrysts. Moreover, some of the quartz plates and portions of some of the felspar plates are disintegrated, the former giving rise to "eye"-shaped areas which exhibit portion of a plate extremely granulated at the margins and corners.

The parallelism and "flow" structure, therefore, are due to dynamic strain, and are not a true flow phenomenon.

Some mica scales are mixed with the granulated quartz areas.

In one place a string of quartz plates occurs, associated with which are grains of a reddish-violet colour. These are isotropic and resemble spessartite.

The rock is a dynamically strained quartz-porphyry with quartz phenocrysts fewer than the felspar.

(ii.) *Weir Dyke*—

$[\frac{1}{1084}]$ about 6½ miles east of Mt. Weir.

A liver-brown, fresh, porphyritic, fine-grained rock, consisting of fairly numerous phenocrysts of felspar in a dense aphanitic ground-mass.

S. Consists of occasional small and large platy or tabular phenocrysts of felspar and more small phenocrysts of quartz in a very fine-grained ground-mass, made up largely of felspar obscured by a fine dust. The latter consists in part of iron ores, in part of green chloritic scales, while small grains and granular aggregates of epidote and zoisite are not infrequent. The felspar is partially kaolinised, of a species difficult to determine, but very acid, with generally a patchy extinction due at times to an intergrowth apparently of two species, at times rather to strain effects. Some untwinned forms are referable to orthoclase.

With the exeception of the chlorite scales, ferro-magnesians are absent.

Many of the felspar phenocrysts have very ragged margins suggesting partial disintegration or resorption.

The structure is undoubtedly igneous and porphyritic, and the rock a felspar--porphyry with few quartz phenocrysts.

(iii.) *Warburton Dyke*—

[$\frac{1}{1041}$] Cassidy Hill.

A purplish-black, felsitic rock with occasional phenocrysts of pink felspar.

S. Consists of occasional ragged turbid kaolinised felspar phenocrysts in a fine-grained ground-mass consisting largely of ragged plates of felspar of which only a very few are twinned, and of occasional plates of quartz. The ground is covered with a fine black dust of which most is black iron ore, but of which some is haematitic.

The felspar phenocrysts are similar to those in previous sections.

The rock is a fine-grained felspar-porphyry with occasional pink felspar phenocrysts. Quartz phenocrysts are either very rare or absent.

[$\frac{1}{1139}$] about two miles north-north-east of Kathleen Hill.

A fine-grained, rather soft, banded yellowish and reddish rock, rather similar to some of the foliated porphyry gneisses.

S. The rock consists of rare phenocrysts of kaolinised felspar in a fine-grained ground-mass composed of quartz and felspar, with bands of coarser quartz mosaic and bands of very fine dense micro-crystalline mosaic, and strings of muscovite mica. There is little doubt the rock is of igneous origin, an altered porphyry, and not a sediment.

[$\frac{1}{1106}$] about one mile east of Camp 55.

A dense black, extremely fine-grained, felsitic flinty rock with occasional distinct phenocrysts of grayish felspar.

S. The rock consists of occasional large, often cracked and partially broken-down phenocrysts of felspar in a micro-crystalline ground-mass of felspar and apparently of quartz, obscured by a minute dust composed in part of chloritic scales, in part of zoisite and calcite granules, in part of granules of black iron ore. The phenocrysts are mostly extremely altered with the production of zoisite grains and needles, or in some cases of kaolin or chlorite scales. The species of felspar, owing at times to zoisitisation, at times to the irregularity in the extinction and twinning, and at times to cracking and partial granulation cannot be determined, but it is apparently in part of intermediate composition—about andesine.

A few patches of greenish or yellowish-green scaly chlorite occur in the ground-mass in addition to the felspar phenocrysts, and these have apparently been derived from green hornblende. The constituents of the ground-mass have been drawn out in fine lines or strings. There is, however, this remarkable character of the ground, viz., that it is cut across in several places by small sharply defined fault lines. There are even some clearly developed trough faults produced. Obviously, therefore, the rock has been subjected to sudden stresses subsequent to the stress which produced the parallel strings or folia.

The structure of the rock is porphyritic, and the rock is classed as a fine-grained flinty, sheared and faulted acid porphyry or rather porphyrite.

[$\frac{1}{1102}$] about 6½ miles north-east of Fort Mueller.

A very fine-grained, felsitic, dark-grey rock weathering to a yellowish tint, and with small phenocrysts of felspar visible in the altered portions.

S. Consists of occasional rather ragged rounded, and partially columnar and tabular phenocrysts of felspar in a ground-mass that is in part a finely crystalline mass of quartz and felspar plates, and in part a more coarsely crystalline mass of rounded quartz and felspar plates partially granulated, and generally with a dotted or spotted appearance resembling a fine granular intergrowth of quartz and felspar. These plates are generally surrounded by the micro-crystalline mosaic. There are a few small quartz grains larger than the constituents of the ground mass, small patches of quartz mosaic and thin quartz veinlets. The whole section is obscured by fine granular dust, yellowish by incident light, and by minute grains of iron ore, while a few strings and patches of brownish chloritic scales and some muscovite scales also occur. A few patches of black iron ore are associated with the latter.

The felspar phenocrysts have in some cases the gridiron structure of microcline which is apparently original and not produced by pressure, in others the characters of orthoclase. Rare elongated forms composed of granular iron ore, chloritic scales, etc., may represent a former ferromagnesian.

The structure of the rock is rather obscure, but a considerable amount of granulation of the constituents has obviously taken place, and there appears to be a fairly distinct, more or less uniform groundmass, with an absence of fragmental structure.

The rock is a fine-grained, considerably weathered felsitic quartz-porphyry.

(c.) Relation of Granites, Gneisses and granular Porphyries to Porphyry Dyke Rocks.

The following descriptions of sections illustrate this relation—

$\frac{1}{1074}$ about half-a-mile south-west of Camp 45.

A reddish, fine-grained, felsitic porphyry finely sheared, exhibiting small phenocrysts of quartz and felspar.

S. Consists of large quartz and felspar phenocrysts in a groundmass, consisting of bands or streaks, some extremely fine-grained, others much coarser in grain, the latter largely quartzose. Both the quartz and felspar phenocrysts show embayment by the ground-mass and uneven extinction, while the felspar phenocrysts show very irregular lamellation. The streaks or bands are curved and wavy and resemble flow lines in some rhyolites. Effects of dynamic strain, however, are pronounced in the rock, being shown particularly in the disintegration of felspar plates, in the extreme irregularity of twinning and extinction, in the fracturing of felspar plates and the curving and bending of the lamellæ. Undoubtedly the alternation of coarse and fine streaks or bands is suggestive of the origin of the rock from a flow, but it is probable that the bending, waviness, etc., are results rather of mechanical deformation (Fig. 54).

The rock, therefore, is a fine-grained quartz-porphyry, extremely sheared, and mechanically deformed by dynamic stress.

[$\frac{1}{1128}$] ¾ mile north-north-west of Camp 67.

A grey, very fine-grained felsitic rock showing small crystals and crystal aggregates of pyrites and minute quartz veins.

S. Consists of a granular mass of quartz plates, very fine in some areas and slightly coarser in others, with occasional rather large ragged plates of quartz granulated at the margins and passing into the mosaic and with small interspersed plates and grains of felspar, and rarely some partially granulated large plates of the same mineral. These latter plates are untwinned and are referred to orthoclase, while some of the small grains in the mosaic show the gridiron structure of microline. Uneven extinction is shown occasionally in the felspar. A few small scales of muscovite, and many minute grains of pyrites are scattered over the mass. The larger quartz plates occur usually in elongated ragged

Fig. 54.

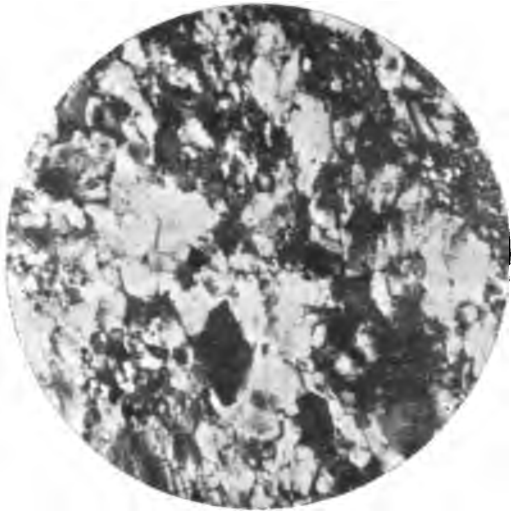

Photo: R. A. Farquharson. Neg. 1626.

[$\frac{1}{1074}$] **Felsitic quartz porphyry with streaky or banded structure resembling that in some rhyolites, but probably a strain effect.**

forms, and there are veinlets or strings of rather coarse quartz mosaic through the mass. Undoubtedly quartz is the chief constituent and the rock has at first sight the appearance of a fine granular quartzite, but the presence of granulated plates of both quartz and felspar and the occurrence of small grains of felspar with the quartz in the mass indicate that it is a fine granular or granulated highly quartzose facies of a quartz porphyry.

Some thin yellowish crystalline streaks are kaolinised felspar with associated pyrites.

[$\frac{1}{1129}$] 1½ miles north-north-west of Camp 67.

A very fine-grained, dark-grey, nearly black rock, with small aggregates of biotite scales. The rock weathers to a light-grey colour and has obviously been considerably sheared.

S. The rock consists of a fine-grained mass of quartz and felspar plates or grains enclosing small patches, some of yellowish-brown or greenish-brown biotite scales and quartz grains, others of biotite scales.

calcite plates and comparatively large plates of felspar with irregular extinction and lamellation, others of biotite scales, muscovite scales, calcite plates and quartz and felspar plates, and others of biotite scales and calcite. Rarely a platy crystal appears in the mass, with the cross-hatching of microcline well developed. Muscovite scales, calcite grains and numerous small biotite scales occur all over the section. Possibly some of the biotite aggregates represent decomposed phenocrysts.

The structure of the rock is fine granular, and it is probable that part at least of the granular mass has been produced by the breaking down of larger plates of felspar and doubtless of quartz.

The rock is difficult to name, but is classified as a granulated biotitic acid porphyry. In hand specimen it shows some resemblance to certain lamprophyres, but the paucity of the ferromagnesian relative to the colourless constituents and the granular or fine platy structure, together with the prevalence of quartz, point to a more acid rock type.

$[\frac{1}{1086}]$ about half-a-mile west of Bob Hill.

A very fine-grained dense dark-grey felsite rock with reddish patches and general reddish tinge, and with occasional small phenocrysts of felspar visible.

S. Consists of occasional turbid platy and columnar phenocrysts of felspar and few smaller phenocrysts of quartz in a ground mass of varying character. In some portions of the slide, the ground-mass consists of a fine micro-crystalline mass presumably of quartz and felspar obscured by a fine greyish or pinkish dust; occasionally there are streaks or cryptocrystalline patches of an undulating form through this mass, more densely charged with pinkish dust, and these obviously curve round the felspar phenocrysts in a manner resembling flow lines. Then there are small patches of quartz mosaic, and small phenocrysts of quartz and felspar partially granulated to a mosaic.

In the ground-mass are occasional small patches of deep-green chlorite, and green chloritic scales are scattered over the slide. Rarely some resorption is noticeable in the quartz phenocrysts.

Species of felspar are too much kaolinised for definite determination, but they appear to be mostly orthoclase.

The structure is clearly porphyritic, but the variations in the ground-mass, the streaking or flow structure and the presence and nearly isotropic nature of the streaks or undulating patches indicate affinities with acid flows, and suggest that the ground-mass was originally glassy, but has been altered (devitrified).

The rock is classed as a felsophyre (of Rosenbusch).

$[\frac{1}{1087}]$ Bob Hill, near Mt. Squires (see fig. 41, p. 93).

A very coarse-grained pink granitic rock, in which large pink felspar crystals and occasional smaller quartz crystals appear in a finer-grained ground-mass. There is a small development of a blackish chloritic mineral.

S. There are large rather ragged plates of kaolinised felspar and quartz, surrounded more or less by smaller felspar and quartz plates, or by a fine-grained intergrowth of quartz and felspar. In places a rounded quartz phenocryst occurs surrounded by small kaolinised plates of felspar, or, rather, felspar punctuated by small grains of quartz forming an intergrowth with the felspar. (Fig. 55.)

Areas of granular quartz and felspar intergrowth, of rod-like intergrowth—rods of quartz in felspar—and of an approach to the graphic intergrowth of quartz and felspar are remarkably frequently developed in the rock, and many of the large quartz and felspar crystals present round boundaries to these intergrowths.

Fig. 55.

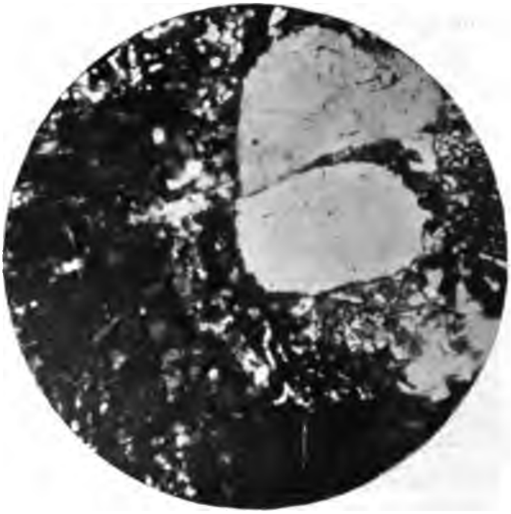

Photo: R. A. Farquharson. Neg. 1627.

[$\frac{1}{1087}$] **The granite porphyry with quartz phenocryst surrounded by quartz-felspar intergrowth.**

Small apophyses from the fine granular intergrowth penetrate the margin of some of the felspar plates, and small quartz grains are visible in places in the felspar plates. Rarely a felspar plate is seen with a border round three sides that has a slightly different orientation and suggests a later growth of the crystal, probably from felspar substance from the ground-mass.

The felspar species are distinctly acid, in part orthoclase, in part an acid plagioclase, while some large crystals show a structure resembling that of microcline. Besides felspar and quartz some patches and flakes of green chlorite occur, with associated epidote, sphene (?), granular iron ore, zoisite, and some plates of epidote, and a rare brownish-yellow flake of partially chloritised hornblende. The structure is more allied to the plutonic than to the porphyritic, but undoubted phenocrysts of quartz occur, and there is enlargement of felspar crystals by the ground-mass.

The rock, therefore, is intermediate between granite and a quartz-porphyry, while the remarkable development of intergrowths of felspar and quartz indicates a resemblance to some granophyres.

[$\frac{1}{1090}$] Cairn, Mt. Squires.

A rather coarse-grained, apparently platy, greyish-pink granitic rock consisting chiefly of plates and felspar.

S. The rock presents a remarkable appearance. It is almost wholly composed of a micro-pegmatitic intergrowth of quartz and felspar. This intergrowth is not uniform, but presents a variety of appearances. In some cases it is a normal form in anhedral plates of quartz and felspar closely approximating to, and often identical with, the graphic structure in some granites. In many cases, however, it is seen to occur on a very minute scale as innumerable minute rods, inclined at an angle to each other on either side of a middle rib. The appearance is very similar to a striation and to the "herringbone" structure observed in the augite of some dolerites or gabbros. (Fig. 56.)

Fig. 56.

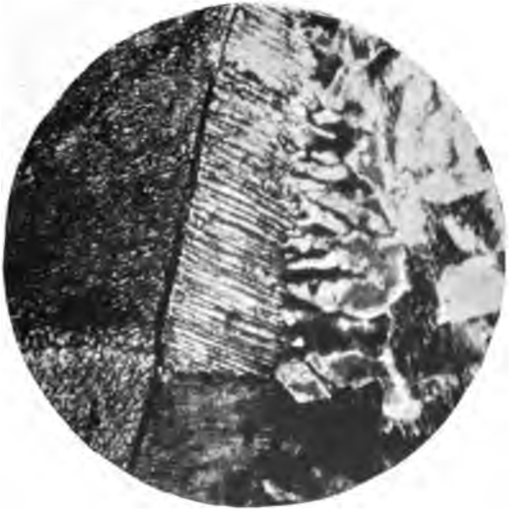

Photo: R. A. Farquharson. Neg. 1628.

[$\frac{1}{1090}$] **The minutely grained micro-pegmatite showing varieties of intergrowth.**

In other cases the intergrowth appears as a plate of innumerable minute dots or grains, probably the result of sectioning the striæ at right angles to their length. Then again, there are cases in which the minute striæ instead of being parallel are more or less radial, or inter-ramifying with each other, producing a minute stringy extinction; or they diverge from a central stem. Again, there are small areas in which the intergrowth appears in forms resembling placoidal fish scales.

Frequently there appears a gradual passage from the minute radial or striated form into the coarser graphic variety. There are occasions in which a euhedral columnar crystal of felspar is surrounded by the dotted and ragged intergrowth, which passes gradually into the coarser variety, and this felspar extinguishes simultaneously with the felspar of the intergrowth itself, a fact indicating their optical continuity.

The intergrowths are in most cases, if not in all, intergrowths of quartz and felspar, a fact which is proved by the evident gradual passage of the coarser quartz and felspar into the rayed varieties. In some of the plates there is a resemblance to the microperthitic intergrowth of orthoclase and albite, but in view of the almost universal occurrence of the micropegmatitic quartz-felspar variety, it is most probable that even in these plates it is the latter.

Only very rarely do plates of felspar occur which are not intergrowths, though large plates of clear quartz are more common. The felspar is in all cases very turbid from kaolinisation, but consists, in the main, of the species orthoclase and microcline.

The large quartz plates occasionally show irregular extinction, but strains effects are generally absent.

There are a few strings of green chlorite scales with associated magnetite grains, a flake or two of green chlorite, and some strings of haematite grains as well as plates of black iron ore, probably magnetite or ilmenite. The original mineral from which the chlorite was derived was not definitely ascertainable. A few rods with high refractive index, high birefringence and straight extinction are referred to zircon.

The structure of the rock is almost wholly micropegmatitic, but in part coarse platy. It is not unlike that observed in some granophyres, but there is no spherulitic structure.

The rock is best described as a micropegmatite, or micropegmatitic granite. Smeeth and Watt[*] in their account of the Horn Expedition to Central Australia, describe a rock named a micro-pegmatite which in almost all respects is identical with this specimen, the only difference being that in one of their rocks they determined the presence of a pale pyroxene.

[$\frac{1}{1089}$] Rock-hole in Creek about one mile south of [$\frac{1}{1090}$].

A pinkish-grey, medium-grained, highly felspathic, granitic rock with numerous thin black chloritic streaks.

S. Consists almost wholly of ragged plates of a slightly kaolinised felspar exhibiting a peculiar roddy or stringy structure in the position of extinction in polarised light. This structure is very similar to that seen in certain oblique sections of microcline. The appearance is undoubtedly due in many cases to an intergrowth of a perthitic nature, of which albite is doubtless one constituent and microcline another. In some plates no twinning is observable, and the species are referred to orthoclase. Incipient granulation is noticeable in some of the plates. Quartz appears to be absent. Through the felspathic mass are a few strings of a brownish-yellow chlorite—at times with biotitic characters—associated with grains of epidote, zoisite and sphene, while some small crystals of prismatic form, high refractive index, high birefringence and straight extinction are referred to zircon. A few doubtful grains may be garnet of the spessartite variety.

The rock is a highly felspathic facies of a microcline granite, with chloritic strings.

[$\frac{1}{1091}$] Camp 51 (east of Mt. Squires).

A very coarse-grained, pink, granitic rock consisting of water-clear quartz and large flesh-coloured platy and columnar felspars with small patches of a black ferro-magnesian.

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[*] The Horn Expedition to Central Australia. Petrology, pp. 82, 85, 86.

S. Consists of very large platy and columnar crystals of turbid kaolinised felspar and smaller irregular plates of quartz, with dense brown and black patches consisting in part of chlorite, in part of deep brown hornblende. The felspar is in large part microcline, though some of the plates showing no determinable twinning are referred to orthoclase. A few columnar turbid crystals with albite lamellation also appear. Quartz is less common than the felspar, and appears mostly squeezed in between the plates of the latter, though in places small quartz plates are enclosed in felspar in a manner suggestive of an intergrowth.

Owing to the denseness of the black aggregates, their composition is difficult to make out, but, while brown biotite and pinkish chlorite are certainly present, there also appear to be prismatic plates of deep brown hornblende. In the felspar are some secondary mineral grains such as zoisite and muscovite; and in the slides are some small crystals of zircon.

Irregular extinction is marked in the quartz plates, and to some extent in the felspar.

The rock is a very coarse-grained biotite-hornblende-microcline granite.

[$\frac{1}{1144}$] about eight miles west-south-west of Camp 65.

Very similar in external appearance to [$\frac{1}{1082}$], but slightly coarser in grain and with distinct crystals of pyrites.

S. Consists of numerous large and small phenocrysts of quartz and turbid felspar in a microcrystalline—in places of cryptocrystalline ground-mass, probably of quartz and felspar. The fineness of the ground-mass seems to be due to the granulation of larger plates. It is obscured again by a fine granular dust.

The felspar phenocrysts are highly turbid from kaolinisation, and are in places carbonated. More pronounced than in [$\frac{1}{1082}$], and much finer in texture are wavy lines or streams of chloritic scales which, sweeping round the phenocrysts, produce an effect resembling "flow" structure. These stream lines are particularly noticeable in the narrow spaces between many phenocrysts. In one case they appear sericitic. As in [$\frac{1}{1082}$], however, they are due rather to dynamical strain than to original flow structures. Embayment of the quartz, resorption, etc., occur as in [$\frac{1}{1082}$].

The rock is essentially identical with [$\frac{1}{1082}$].

[$\frac{1}{1145}$] about six miles west-south-west of Camp 65.

A highly porphyritic, dark-grey rock with many square and columnar phenocrysts of pink felspar, some of large size, and numerous smaller quartz phenocrysts in a very dark-grey felsitic ground-mass.

S. Consists of many large rounded phenocrysts of quartz, and many large tabular, columnar and irregular phenocrysts of kaolinised felspar in a ground-mass that is mostly microcrystalline, but in parts coarse-grained, and then seen to be composed of quartz and felspar plates and grains of calcite. Rarely there is a ragged more or less fibrous plate or column of pale-green hornblende among the phenocrysts, sometimes with associated grains of magnetite. Enlargement by the ground-mass is noticeable in the quartz and felspar and resorption borders appear in the quartz. The felspar is of a very acid species, in part orthoclase, in part an intergrowth of two species or a chequered twin. There is a faint suggestion of the "flow" structure noticeable in [$\frac{1}{1084}$].

The rock is a coarsely porphyritic quartz-porphyry with very large phenocrysts. Similar essentially to $[\frac{1}{1054}]$, $[\frac{1}{1074}]$, and $[\frac{1}{1084}]$.

3. **Clastic Rocks.**

$[\frac{1}{1088}]$ about seven miles east-south-east of Camp 49.

A dirty, dull-green, much decomposed, rather fine-grained rock, not unlike in hand specimen another specimen from the same locality (see footnote to $[\frac{1}{1088}]$ on page 183).

S. In ordinary light, the rock has a distinctly fragmental and tufaceous appearance. There are angular clear fragments, yellowish-green chloritic forms, and pale grey granular forms. Under the microscope in ordinary light, the fragmental character is easily seen. There are angular and irregular yellow-green chloritic forms, some dotted with granular iron ore, clearer forms somewhat rounded and composed (a) of platy quartz, (b) of chloritic scales with quartz grains and some felspar grains, (c) of opaque grey granular zoisite and chlorite, (d) of fine granular cryptocrystalline, nearly isotropic material, (e) of nearly isotropic material with angular quartz grains, very similar to the mass of $[\frac{1}{1078}]$

There are in addition, some felspar crystals, and the chloritic forms are in places drawn out in streaks. So far as can be made out, there are no fragments definitely of rock types, though some may be decomposed glass, others may be portion of the greywacke of which $[\frac{1}{1078}]$ is a specimen, and others again may be the remains of rock types decomposed beyond recognition.

The rock is difficult to classify accurately. In some respects it resembles a highly chloritic greywacke, in others an altered tuff or ashy agglomerate. Everything considered, it is more probably the latter.

$[\frac{1}{1085}]$ 5½ miles west of Mt. Squires.

A dark grey-green, fragmentary rock with a slightly sheared structure, in which fragments of various sorts and sizes are visible. Some consist of greenish flinty material, others of white flinty quartz; some are yellowish. Some are very large—more than an inch across—and the size varies from this to very small grains just recognisable with the naked eye. All are enclosed in a fine-grained greyish-green matrix which makes by far the most of the rock-mass.

S. Sections show a decided fragmental structure. There is a very fine-grained opaque grey granular mass which is practically isotropic, enclosing small grains of quartz and felspar and minute grains of epidote or zoisite, and enclosing a considerable number of larger fragmentary angular forms. These latter are interesting. Some consist of a minute cryptocrystalline mosaic of quartz, others are undoubtedly of igneous and probably of volcanic origin, consisting of an indistinct reticulated mass of felspar needles obscured by opaque grey granular material; others again consist of very small ragged laths of felspar as in some albite porphyries; others again consist of a micro-crystalline mosaic of quartz in which small platy felspar is identifiable, and in which there are relics apparently of disintegrated quartz phenocrysts as well as small chloritic scales. Others consist of a fine plexus of rods of felspar with the interspaces occupied by grey opaque material and scales of green chlorite; and others are similar to these, but consist of small rods of felspar lying in all directions, partially kaolinised, and with associated green chloritic scales and small opaque grey granular zoisitic or epidotitic material. These latter resemble the groundmass of [$\frac{1}{1125}$]. In some of the forms granular calcite is present.

The matrix is fine granular, grey, and practically isotropic.

There is a marked parallel stretching of the matrix in some places, probably the result of shearing.

The matrix closely resembles that of a sedimentary rock, especially a greywacke, while the included igneous and possibly volcanic fragments suggest a resemblance to some volcanic agglomerates.

From the structure and composition of the matrix, however, it is probable that the rock is best interpreted as a sheared greywacke with enclosed igneous and probably, in some cases, volcanic fragments. In this connection it is interesting to point out that the rock from Mt. Yagahong, an arkose with agglomeratic affinities, has several characters in common with this rock, especially as regards the apparent sedimentary structure and the nature of the included fragments.

A pebble taken from [$\frac{1}{1085}$].

A small pebble, much weathered, dirty grey in colour and somewhat porphyritic.

S. Consists of highly altered—chiefly zoisitised—phenocrysts of felspar in columnar and squarish forms, in a fine-grained ground-mass, composed of a loose rectangular network of thin acicular laths of felspar interspersed with fine granular or platy felspar. Both the laths and the plates are ragged or uneven in outline. With hardly any exception, the phenocrysts are so completely altered to granular and fine prismatic zoisite that their optical properties have been destroyed. In places in the ground are ragged scaly aggregates of green chlorite, and all over the sections are small opaque grey granular aggregates, white by incident light and probably of zoisite, though some may be leucoxene derived from ilmenite. Rather common in the rock are long needles of apatite.

The rock is very difficult to name. It is undoubtedly porphyritic, and judging by the fact that the felspars are generally altered to zoisite, its composition appears to be rather basic. There is no trace of original ferro-magnesian, and the structure of the groundmass is unusual. It will be best described for the present as a zoisitised and chloritised porphyrite.

[$\frac{1}{1103}$] Hill 2¼ miles west of Camp 55.

A fine granular white quartz rock with pale reddish iron staining, and with numerous small whitish and pale reddish or yellowish granular spots. There is a tendency to fine cleavage visible in the specimen.

S. Consists of a rather fine-grained mass of more or less rounded partially interlocking plates of quartz, with here and there ragged aggregates of a mineral with a rather high refractive index, definite cleavage, straight extinction on all prismatic edges and on the cleavage traces, weak birefringence and biaxial character. Amongst the plates are occasionally small prismatic forms. The mineral is in all cases turbid from alteration (probably kaolinisation), and in general appearence in ordinary light resembles highly turbir felspar. There are, moreover, in it inclusions of brown-yellow rutile needles and occasionally of small flakes of muscovite. The powdered mineral gives a decided blue colour or ignition with cobalt nitrate. It resembles cyanite, andalusite and zoisite, but from the straight extinction on prismatic forms, the blue reaction with cobalt nitrate, and the low birefringence, it is referred to andalusite.

The rock is a metamorphic quartzite with granular andalusite.

$[\frac{1}{1105}]$ Hill about one mile east of Camp 55.

S. The sections present an unusual appearance. They are chiefly composed of a very fine-grained, dense-black, dusty material, sometimes with small patches of brown-yellow micaceous scales, sometimes devoid of them, and in places with small irregular quartz grains. The dusty black material appears to be of amorphous graphitic origin. Included in these patches or associated with them, are (a) irregular clear patches of quartz and felspar with some included black graphitic material; (b) more or less rounded brownish-yellow biotitic forms nearly devoid of graphitic dust; (c) lighter-coloured forms extremely fine-grained, but composed in part of minute yellowish scales and graphitic dust with or without angular quartz grains; (d) small forms consisting of an indistinct plexus of felspar laths, resembling those found in the conglomerate previously described; (e) cryptocrystalline and nearly isotropic forms dusty with graphitic material; (f) occasional angular quartz and felspar crystals of some size. In places the graphitic and chloritic material is streaked out as if along a zone of shearing.

The structure of the rock is somewhat obscure, but apparently fragmental, and the specimen is classed as a black graphitic agglomerate.

$[\frac{1}{1073}]$ about 1¾ miles north-east of Camp 45.

There are two specimens from about the same locality.

(a.) This is a fine-grained yellowish-white intensely sheared micaceous schist, with much muscovite on the shear surfaces.

S. Consists of a granular or small platy quartz mass in which are numerous elongated flakes and more or less parallel strings of colourless muscovite, though most of the rock is composed of quartz and mica, and it is probable that the mica represents original felspar now almost wholly altered. There is no trace of phenocrysts. The quartz plates are all small and interlocking.

The rock is an intensely sheared mica schist. Its origin, whether from an igneous rock such as an aplite or a granular quartz porphyry, or from a felspathic sandstone is not clear. The structure of the quartzose mass is that observable in certain granulated aplites, so that it is more probably derived from a porphyry or aplite than from a sediment.

(b.) This specimen is also intensely sheared, almost foliated, but differs from (a) in being pale-green in colour with numerous pale-green micaceous spangles, as well as brown-red micaceous patches on the shear surfaces. The rock obviously consists chiefly of white quartz and the brown-red and pale green micaceous scales.

S. In section, the rock consists of a mass of numerous small rounded more or less interlocking grains of clear quartz, in which are many small ragged pale yellowish-green micaceous scales separate and in aggregates. The scales are often slightly pleochroic, and in places are distinctly chloritic. In cross sections of the rock, they appear in irregular bands or strings, and at times these strings are coloured intensely red by red oxide of iron. The structure of the rock is again fine-granular or irregularly platy. No felspar was determined in the sections examined.

The rock is of rather peculiar and undeterminable character, but appears to be a green micaceous and chloritic intensely sheared quartzite, possibly of sedimentary origin. In default of an estimation of the amount of alumina in the rock, it is difficult to determine for certain whether the micaceous mineral is muscovite or talc, though it appears rather to be the former.

Both (a) and (b), therefore, are of rather doubtful origin, though differing considerably in appearance, they nevertheless have some points in common, but from the absence of field evidence—owing to the circumstances under which the rocks were collected—and from the indefiniteness of the structure of the rocks, little more of a definite character can be said of them.

$[\frac{1}{1060}]$ Five miles north-north-east of Camp 42.

A dull dark-grey, rather fine-grained granitic rock, with small patches and innumerable minute scales of black biotite. The rock has been slightly sheared.

S. Consists of many large angular and more or less rounded platy crystals of quartz, and angular platy and irregular crystals of felspar in a fine-grained ground-mass or matrix of quartz and felspar enclosing numerous small scales and flakes of brown biotite, scales of muscovite, grains of calcite, sphene, etc. In all cases, the large plates, though appearing as phenocrysts in a fine-grained ground-mass, are very angular, with cracks, serrated margins and general fragmental character. In spite, however, of the irregularity in outline, there seems to be little if any granulation of the margins, and such effects of dynamic strain as uneven extinction, secondary lamellation of the felspars, etc., are by no means pronounced.

The ground-mass or matrix is quite fine-grained, but not uniform in texture, some portions being comparatively coarse, while small rounded areas of almost cryptocrystalline mosaic occur. There appears, however, to be a gradation in size between the large plates of quartz and felspar and the fine granular mass, crystals of both quartz and felspar of all intermediate sizes being common. The ground mass is generally obscured by the numerous scales of brown biotite and colourless muscovite. The species of felspar present are difficult to determine, but orthoclase and an acid plagioclase are the most common.

The important question in regard to this rock is whether it is to be regarded as of clastic or igneous origin, *i.e.*, whether the fragmental appearance is due to aggregation and consolidation of mineral fragments, or is the result of crushing and granulation of an igneous rock. There is no question that the large angular pseudo-phenocrystal plates have a clastic appearance. Moreover, effects of severe dynamical strain are largely absent, and many of the most angular of the plates show no strain phenomena at all. If, however, their angular nature were the result of pressure or crushing stress, they would certainly be expected to show some at least of these phenomena, such as optical anomalies, granulation, and a tendency to foliation. These characters are almost wholly absent.

On the other hand, the ground-mass in general has the appearance of that of many quartz porphyries, *i.e.*, of a granular mosaic of quartz and felspar, and is certainly more igneous in structure than clastic, notwithstanding the fact that there is considerable variation in its texture. It is possible, of course, that a certain amount of recrystallisation of an original fine-grained clastic matrix may have resulted in a mass with a structure resembling that of igneous rocks.

On the whole, the balance of evidence is rather in favour of a clastic origin of the rock, and the latter is interpreted as a somewhat sheared pseudo-porphyritic granitic arkose, with a profusion of small biotite scales.

B.—BASIC IGNEOUS ROCKS OF DOUBTFUL POSITION.

1. Basic plutonic and dyke Rocks.

[$\frac{1}{1099}$] Fort Welcome (Cavenagh Range).

A rather coarse-grained black rock with reflecting surfaces of numerous columnar twinned crystals of a plagioclase felspar, and a somewhat greasy lustre.

S. Most of the rock is made up of large columnar and platy crystals of felspar, with pronounced albite, and occasionally pericline lamellation. The species is basic, and from the extinction angles in symmetrical lamellae, it is basic labradorite, or bytownite. In addition to the felspar there is a small development of ferro-magnesians. Of these the chief appears to be hypersthene in grains and anhedral forms often in ophitic relationship with the felspar. The mineral is generally markedly pleochroic in pinkish to pale-green tones, sometimes with distinct schiller structure. Rarely an alteration is noticeable in it to green chlorite. through a greenish hornblende. In addition to the hypersthene there are anhedral plates of a monocline pyroxene often with a border of hypersthene wrapping round them, and some granular forms referred to olivine.

The structure is distinctly ophitic.

The rock approximates to an anorthosite in the extremely large development of felspar, but is a highly felspathic hypersthene-olivine gabbro, or olivine-norite.

[$\frac{1}{1098}$] Camp 53 (Cavenagh Range).

Another nearly black, rather coarse-grained, highly felspathic rock, very similar in appearance to [$\frac{1}{1099}$].

S. Rounded and anhedral plates and grains of pyroxene and olivine occur in more or less clear ophitic relationship with columnar and platy striped plagioclase. (Fig. 57.) The hypersthene is in rounded grains and irregular platy forms, with pinkish and pale-green pleochroism and generally without schillerisation.

Associated with it but mostly in anhedral plates is a schillerised colourless diallage. In some cases small grains of the hypersthene occur in diallage plates suggesting an intergrowth of the two minerals, which in this case are easily distinguished both by the different optical orientation and by the absence of schiller structure in the hypesthene. Plates of diallage without schillerisation however, are not uncommon.

In addition to these minerals, in common association with the pyroxene, are rounded grains referred on account of the absence of cleavage, high refractive index and birefringence, presence of cracks, etc., to olivine. A slight tendency to schillerisation is noticeable in them, and at times a very faint yellowish pleochroism. They sometimes are in ophitic relation to the felspar. The felspars are faintly clouded by inclusions or by incipient kaolinisation, but are again basic labradorite.

Fig. 57.

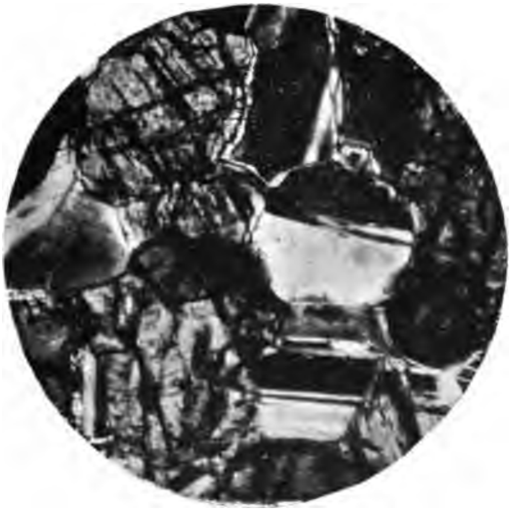

Photo: R. A. Farquharson. Neg. 1629.

$[\frac{1}{1098}]$ **The olivine-norite, showing the granular nature of the ferro-magnesian and the indistinct ophitic structure.**

The rock is one of the enstatite-augite series, an olivine-diallage gabbro or olivine-norite.

$[\frac{1}{1101}]$ Fort Mueller (Cavenagh Range).

Similar in appearance to $[\frac{1}{1107}]$ but much finer in grain, with some light-grey plagioclase felspar showing.

S. In this section, the ferro-magnesians are nearly as common as the felspar. There are large columns and plates of striped basic labradorite, and rounded grains and plates of pleochroic hypersthene, with occasional anhedral plates of highly schillerised diallage. Orthopinacoidal twins in the diallage give a herring-bone structure to these plates. While many of the plates of hypersthene do not show schillerisation, others are finely schillerised. Granular forms of the hypersthene occur apparently enclosed in diallage plates, and the two minerals are generally closely associated in a pyroxene aggregate. Olivine is apparently absent. An ophitic structure, in which columnar felspar is enclosed in the pyroxene—diallage sometimes on one side and hypersthene on the other—is occasionally visible.

The rock is a hypersthene-gabbro, but though differing a little from the two former in composition, is doubtless genetically connected with them. It closely approximates to some of the norites from different portions of the Western Australian Goldfields.

[$\frac{1}{1107}$] Camp 56 (east end of Blackstone Range).

Similar to [$\frac{1}{1099}$], but coarser in grain, with large platy felspars and greyish-black tint.

S. Resembles closely [$\frac{1}{1099}$], but ferro-magnesians are more common. The felspar again is large columnar and platy, often with a fine schiller structure. Hypersthene is again commonest of the ferro-magnesian minerals, but olivine in granular as well as tapering forms is not infrequent, and often there is a border of hypersthene between the olivine and the felspar (Fig. 58). A faint schiller structure is sometimes visible in the olivine forms as well as a brown-red staining along cracks in the mineral, and sometimes there is a decomposition to a highly birefringent brown-red mineral referred to iddingsite. In some cases where an envelope of hypersthene is present, the latter, especially where in contact also with iron ore, has been altered to or is associated with a brown pleochroic hornblende. Some anhedral plates of monocline pyroxene occur. The felspar is in ophitic relation to the ferro-magnesian.

Fig. 58.

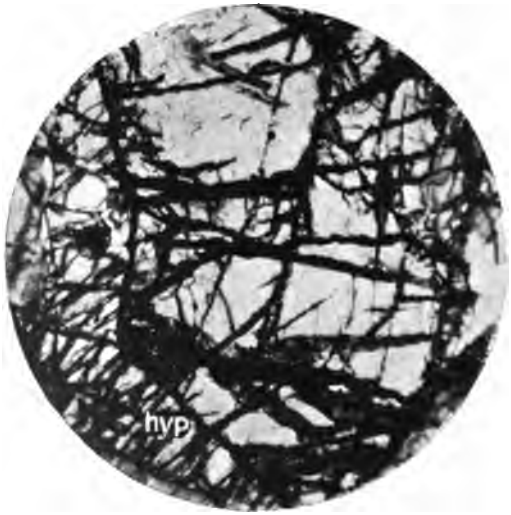

Photo: R. A. Farquharson. Neg. 1630.

[$\frac{1}{07}$] **Coarse-grained olivine-norite, with border of hypersthene round the olivine.**

The rock is similar to [$\frac{1}{1099}$]; like it, it is of the enstatite-augite series.

The specimen is a hypersthene-olivine gabbro or olivine-norite, and both specimens closely resemble the norite from Norseman, and are probably genetically connected with it.

[$\frac{1}{1119}$] Four miles west of Lightning Rock. Dyke in granite [$\frac{1}{1097}$].

A medium to fine-grained black rock similar to [$\frac{1}{1135}$] but finer in grain.

S. The chief constituents are augite and felspar.

The former is in large and small grains and plates, colourless in section, and occasionally showing a tendency to crystallise boundaries, while the forms are generally fresh, some show a margin of green chlorite and rarely of green chloritic hornblende, while occasional scales of green chlorite and hornblende occur in the felspathic mass.

The latter is fairly abundant, more common than the ferro-magnesians, slightly kaolinised, in columnar crystals highly twinned on both the pericline and albite laws and to a smaller extent in irregular plates with uneven extinction and twinning. The species is about bytownite.

There are small areas of a micro-pegmatitic intergrowth of quartz and felspar on both a very fine and a fairly coarse scale, while a little interstitial quartz also occurs.

Flakes of brown biotite are not infrequent, and apatite needles as well as large grains of black iron ore (probably ilmenite) are quite common. Leucoxene in this, as in the other previous dolerites of this series, is not noticeable.

There is a pronounced ophitic structure in the rock. (Fig. 59.)

Fig. 59.

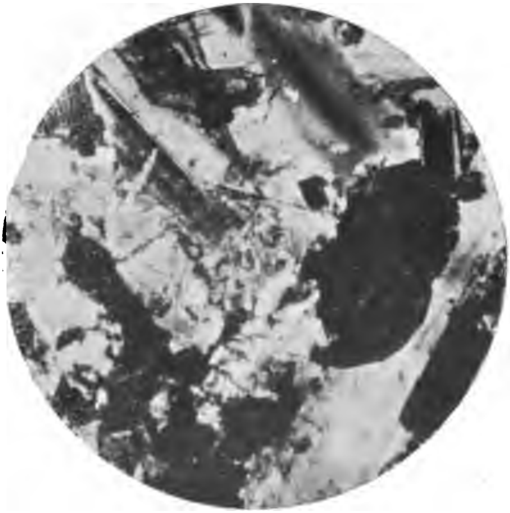

Photo: R. A. Farquharson. Neg. 1631.

[$\frac{1}{1119}$] **The micro-pegmatitic quartz-dolerite.**

The rock is a micro-pegmatitic quartz dolerite, with flakes of biotite.

[$\frac{1}{1135}$] 7¾ miles south of Bentley Hill. Dyke in granite [$\frac{1}{1134}$]. A fresh, medium-grained rock with numerous reflecting surfaces of augite and felspar crystals.

S. The chief constituents are augite, olivine, and felspar.

The augite is in anhedral plates of a grayish or a reddish-violet colour, extremely cloudy and opaque from the presence of a dense dust. There is often a distinct schiller structure in the forms.

The olivine is in rounded, oval and irregular grains, with numerous cracks and at times a faint schiller structure. Decomposition of the mineral is frequently pronounced, the products being strings of black magnetite granules, some chlorite scales and a brownish or reddish biotitic mineral referred to iddingsite. Rarely a small plate of a mineral very similar to the olivine, but with an apparent cleavage and straight extinction on this cleavage, is to be observed and is referable with doubt to hypersthene. Some plates of brown biotite are noticeable.

The felspar is very abundant, in very well outlined columnar crystals forming a plexus, and slightly kaolinised. The species is about bytownite, and both albite and pericline lamellation occur. In some of the forms there is irregularity both in the extinction and in the twinning. Apatite needles and grains of iron ore are fairly common, but quartz is apparently absent. (Fig. 60.)

Fig. 60.

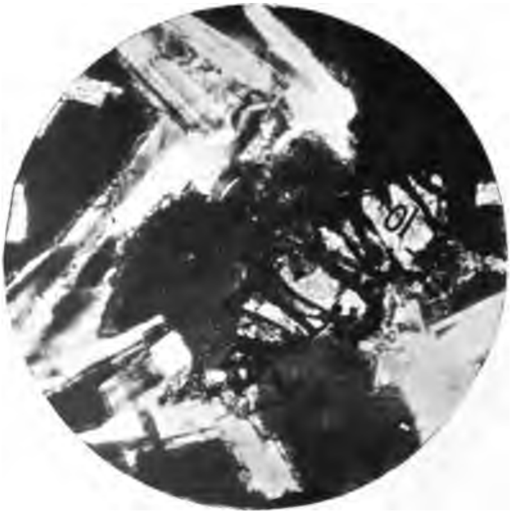

Photo: R. A. Farquharson. Neg. 1632.

[$\frac{1}{1135}$] **The ophitic olivine-dolerite dyke rock.**

The structure of the rock is pronouncedly ophitic. The rock is an ophitic olivine-dolerite with biotite flakes.

[$\frac{1}{1063}$] 15 chains south-west of Camp 43. From a line of boulders apparently marking the site of a dyke intruding granite like [$\frac{1}{1064}$].

A fairly fresh, medium-grained black rock with numerous reflecting surfaces of augite and felspar and a little brown iron staining.

S. The chief constituents are augite and felspar. The former is in fairly large irregular platy forms, nearly all of which are characterised by a greyish or pinkish-violet colour produced by countless minute scales and needles arranged with their long axis parallel, and appearing as a fine dust. This dust frequently produces a schiller effect. Some of the plates show a border of green chlorite, others are almost completely altered to green scaly chlorite with an interior of black magnetite or titanomagnetite dust, and others are probably altered to green pleochroic hornblende. Associated with the green chlorite and with aggregates of grains of iron ore are scales and flakes of brown biotite. The chlorite is frequently, especially near the iron ore, heavily stained brown. Occasionally, orthopinacoidal twinning is present in the augite. The felspar is more plentiful than the ferro-magnesians, is most commonly in long columnar crystals forming a plexus, and is slightly turbid from the kaolinisation. The columns show both albite and pericline twinning, and the species is a very basic one, about bytownite or basic labradorite. There is a well marked ophitic structure in the rock, the felspar columns being often partially or completely moulded by the augite. There is a little interstitial quartz in small grains and plates, and apatite needles of some size are not uncommon.

The rock is a rather coarse ophitic quartz-dolerite, with flakes of brown biotite.

2. **Basaltic Dolerite.**

[$\frac{1}{1100}$] Near Fort Welcome Spring, Cavenagh Range.

A very fine-grained, nearly black, basaltic rock.

S. Consists of a dense mass of minute, nearly colourless, pale-green, fibrous prisms of hornblende in which are small thin short laths of turbid felspar. The mass is to a small extent charged with grains and strings of magnetite. In it, further, are some obscure chloritic—and in some cases apparently six-sided—phenocrysts, some small fibrous hornblende phenocrysts, and some apparently platy phenocrysts of felspar which are obscured by grains and rods of the hornblende. The rock is much decomposed. The structure, however, was apparently originally finely doleritic.

The rock is a weathered form of a fine-grained basaltic dolerite of phenocrystal character, in which the original granular augite has been altered to fibrous hornblende and ferro-magnesian phenocrysts to chlorite as well as to hornblende.

[$\frac{1}{1088}$] About seven miles east-south-east of Camp 49.*

A much decomposed, dirty brownish-green, fine-grained rock.

S. The rock has been much decomposed but consists of a rather coarse plexus of columnar or lath-shaped felspars, considerably obscured by aggregates of yellowish and yellowish-green chloritic scales amongst which occasional greyish-violet grains and prisms of fairly fresh augite, granular magnetite and granular ilmenite surrounded by leucoxene occur. The felspars are mostly kaolinised and nearly isotropic. There is much yellow iron-staining especially in the chloritic patches, and needles of apatite are frequent. A few quartz grains, probably of secondary origin, appear in the plexus.

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* Two specimens, taken a few yards apart, bear the same number; the other is described on page 174.

The structure of the rock was undoubtedly ophitic.

The rock is a much altered, chloritised ophitic dolerite.

[$\frac{1}{1109}$] Hills about four miles west-south-west of Camp 57 (near Mt. Aloysius).

A fine-grained, almost black, basaltic rock.

S. In section it proves to be a fine-grained ophitic dolerite, identical with the Sandstone dolerite (and Meekatharra dolerite) but somewhat weathered—chloritised.

C.—TOWNSEND RANGE SERIES.

1. Sedimentary Rocks.

[$\frac{1}{1080}$] 7½ miles north-east of Depot Camp.

A medium-textured, fragmental rock made up of many liver-brown, blackish, greenish, rounded and angular fragments, with a cement that is generally fine-grained and greyish, but sometimes

Fig. 61.

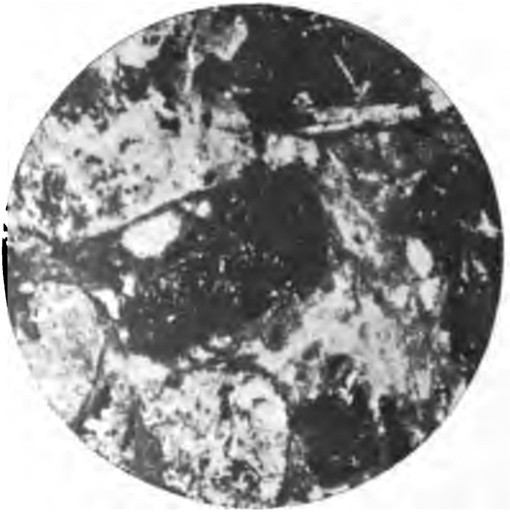

Photo: R. A. Farquharson. Neg. 1633.

[$\frac{1}{1080}$] **The volcanic conglomerate showing the pebbles and the nature of the matrix.**

calcareous. The rock shows a resemblance to a "pudding-stone" conglomerate.

S. Undoubtedly a volcanic agglomerate consisting of rounded and angular fragments of various volcanic facies; of pinkish glassy material of fine-grained dolerite; of quartz-porphyry; of flinty microcrystalline quartz; of a black, dense, probably doleritic or andesitic type such as occurs on the margins of some dolerite dykes at Sandstone and Cue; of glassy forms partially altered to greenish isotropic chlorite; of angular quartz crystals and felspar crystals, and fragments altered partially to granular zoisite; of forms composed of a plexus of felspar microlites with interstitial pale green albite; of dense black andesitic forms:—all in a sparse matrix composed in part of nearly isotropic glassy material, sometimes with indistinct flow lines and altered to zoisitic material, and in part platy calcite and chlorite. (Fig. 61.)

Many of the forms of the fragments show only partial crystallisation and were obviously only emerging from the glassy condition at the time of consolidation. A bending of the lamellation of the calcite plates is occasionally visible. The rounded character of many of the forms is due either to rolling in the volcanic vent or to attrition after settling, probably under water.

The rock is undoubtedly a basic volcanic conglomerate of andesitic or basaltic nature.

A full description of the fragments will be entered upon later. It may be said here, however, that the quartz-porphyry fragment observed is fairly certainly similar to the porphyries already described, and that some of the doleritic fragments closely resemble one of the dykes in the gneiss and gabbro and the brownish rock from Table Hill.

[$\frac{1}{1120}$] Two miles north-east of Frank Scott Hill.

An obviously clastic rock of dark-grey colour, consisting of rounded black fragments, at times an inch square in cross section, at other times quite small; at times, especially in the case of the larger, distinctly porphyritic and resembling some of the Warburton acid porphyries; at other times dense black—all enclosed in a fine-grained, dark-grey siliceous matrix.

S. In section, the distinction between pebbles and matrix in hand specimens is seen to be more one of degree than of kind. There are large rounded, angular and irregular fragments of various rocks surrounded by an apparent matrix of rounded grains of clear quartz and small fragments of clouded felspar, but amongst the latter are smaller fragments similar to the larger forms. The round quartz pebbles and the small felspar fragments, however, are, in places cemented together by a fine granular quartz matrix, so that, as regards structure, the rock is composed of large rounded, angular and irregular forms enclosed in a matrix of round quartz and more or less angular fragments, and this matrix is itself cemented together by fine granular quartz mosaic. (Fig. 62.) The larger fragments consist of:—

1. Acid porphyry composed of clouded felspar phenocrysts in a fine-grained, dense, nearly isotropic ground-mass of small plates obscured by a minute dust but presumably of felspar, with a few recognisable plates of quartz. This porphyry closely resembles certain varieties of the Warburton porphyries, the facies best described as felspar porphyries.

2. Similar smaller forms pinkish in section, but without phenocrysts. Some of these consist wholly of a minute plexus of indistinct felspar laths with, in some cases, undulatory or wavy extinction. Others are practically crystalline.

Fig. 62.

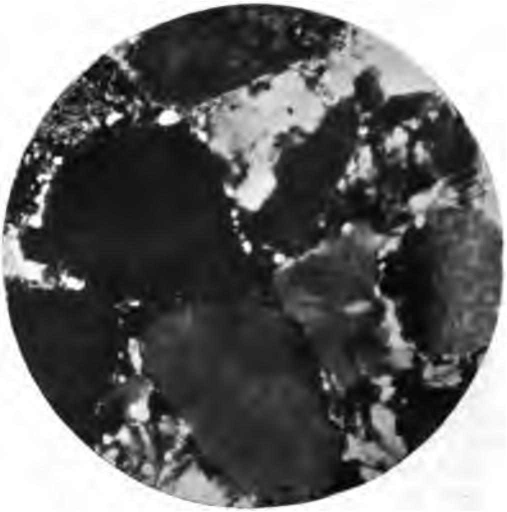

Photo: R. A. Farquharson. Neg. 1634.

[$\frac{1}{1120}$] **The normal conglomerate, showing the pebbles and the matrix.**

3. Other forms are rounded or oval and dense black, apparently from black iron-ore dust.

4. Others consist of a plexus of felspar laths or needles with the interspaces occupied by dense black material.

5. Some are yellowish pink, almost quite isotropic and obscured by fine black dust. These somewhat resemble glassy fragments.

The smaller fragments consist of forms generally similar to these, but in addition:—

1. Round quartz grains.
2. Rounded and angular felspar crystals.
3. Fragments of a micropegmatite.

The fine-grained matrix consists largely of quartz mosaic, but with felspar grains, and in places green chlorite scales, and scaly aggregates.

The rock is a conglomerate of which the fragments are chiefly acid porphyry, and of which the matrix consists of round quartz and fewer felspar forms, themselves cemented together by a fine-grained quartz, or, in places, quartz-felspar mosaic.

[$\frac{1}{1042}$] At foot and to south of Cassidy Hill.

A fine-grained, greyish-green siliceous gritty rock.

S. Consists chiefly of many very small angular and rounded grains of quartz, and considerably fewer grains of slightly kaolinised plagioclase felspar, all cemented together by an extremely fine-grained matrix of minute grains or plates of quartz forming a kind of micro-crystalline mosaic. Scattered more or less commonly through this mass there are also scales of green chlorite, grains of black iron ore, rods and grains of epidote, small fragments of a mineral referable to leucoxene, small scales of colourless muscovite and minute, opaque gray, granular aggregates referred to zoisite.

The structure of the rock is clearly clastic, with a secondary siliceous cement. (Fig. 63.)

Fig. 63.

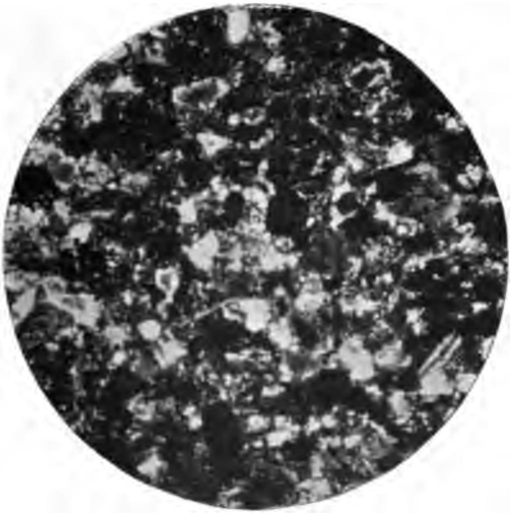

Photo: R. A. Farquharson. Neg. 1635.

$[\frac{1}{1042}]$ **The fine-grained chloritic grit.**

The rock is a fine-grained chloritic quartz-felspar grit.

$[\frac{1}{1043}]$ at foot and to south of Cassidy Hill.

A dark brownish-black, rather fine-grained gritty rock.

S. Consists of numerous small rounded and angular quartz grains, larger and angular kaolinised felspar grains, and angular, sometimes blackened, fragments of an indistinct rock type obscured by the black dust, in a fine-grained cloudy kaolinic and sericitic mass which is at times in platy form, and at others in strings round the grains. It is doubtless due to the alteration of the felspar of the mass or matrix. The sericitic strings are arranged in more or less parallel alignment as if produced by dynamic stress. Some greenish and yellowish chloritic scales occur in places in the section. The matrix encloses one large angular fragment of a fine-grained felspathic rock with few phenocrysts and obscured by black granules which in places form a dense black mass. The phenocrysts of this form are all small and very ragged, but the form resembles some varieties of felspar porphyry.

There is little doubt that the rock, though much weathered, is a sericitic quartz-felspar grit with enclosed rock fragments.

[$\frac{1}{1121}$] 5¼ miles north of Depot Camp.

A rather fine-grained, greenish, gritty rock, with indistinct reflecting surfaces of carbonate. Parts of the specimen are banded by much finer, dense bands of flinty appearance.

S. Consists of a mixture of greenish chloritic flakes, granular and irregular platy carbonate, small angular and irregular fragments of quartz, and occasional fragments of felspar, rounded brownish and black earthy isotropic forms, and small rounded forms of microcrystalline or cryptocrystalline silica. Structure is indefinite, mainly granular or fine platy; and the general microscopic characters are obscure.

The rock appears to be a chloritic calcareous grit, but the sedimentary or clastic character is not distinct. It is possible that the rock is a highly altered—chloritised and carbonated—form of an original amphibolite, but this is less probable than the former view. The crystalline character of much of the carbonate suggests that a recrystallisation of the granular carbonate has taken place to some extent.

[$\frac{1}{1079}$] About seven miles north-east of Depot Camp.

The partially crystalline fine-grained calcareous grit described above. There is a kind of banded structure in the section in ordinary light, due to lines of grains of iron ore (ilmenite, etc.)

[$\frac{1}{1078}$] About five miles north-east of Depot Camp.

A fine-grained, dull grey-green rock, with a suspicion of shear structure and a gritty appearance.

S. In ordinary light, it consists of numerous small, mostly angular grains of quartz and fewer of felspar, in an opaque dusty mass in which scales of greenish chlorite, small ragged plates of calcite and various more dusty round and irregular outlined forms occur.

In polarised light, there are the grains of quartz and felspar, small grains and patches of calcite, and a little micacised felspar, in matrix that is almost completely isotropic, but in which indistinct outlines of dense fragmental forms can be seen. With high powers, the isotropic mass is seen to consist in part of chlorite scales, in part of zoisitic grains, in part of kaolinic or earthy material.

The structure of the rock is distinctly fragmental.

The rock is best described as a chloritic earthy grit, or better, as a fine-grained chloritic gritty greywacke.

[$\frac{1}{1146}$] Townsend Range, near Depot Camp.

A pinkish, fine-grained, granular quartz rock.

S. Consists of very small rounded quartz grains of uniform size cemented by a small development of quartz that is in places slightly reddish or pinkish from iron oxide. The secondary cement not always visible. Uneven extinction is noticeable in some of the grains, but not in most.

The rock is a sedimentary compact quartzite of very even grain.

2. Volcanic Rocks.

$[\frac{1}{1122}]$ near Mt. Herbert (see Fig. 43).

A fine-grained, dark-green rock, with frequent, small, rounded, yellow areas, some epidotic, some zoisitic, and others quartzose.

S. The mass of the rock consists of a fine plexus of laths or small slender rods of felspar with the interspaces occupied by a black dust probably magnetite, a few green chloritic scales and flakes and small grains and granular masses of yellow epidote. In some portions of the slide the plexus is very minute, the felspars being only needles. Suitable sections for determination of the felspar are rare, but the species is at least as basic as andesite. Augite was not definitely recognised, but some greyish opaque granular forms may represent it, though many of these are undoubtedly epidotic.

The rounded yellowish forms are mostly composed of granular and platy epidote and platy quartz, but in some granular zoisite is to be seen and in others granular calcite, while occasionally some small platy turbid felspar is associated with the quartz. From their form and composition they appear to resemble more closely infilled pores or vesicles than decomposed phenocrysts. (Fig. 64.)

Fig. 64.

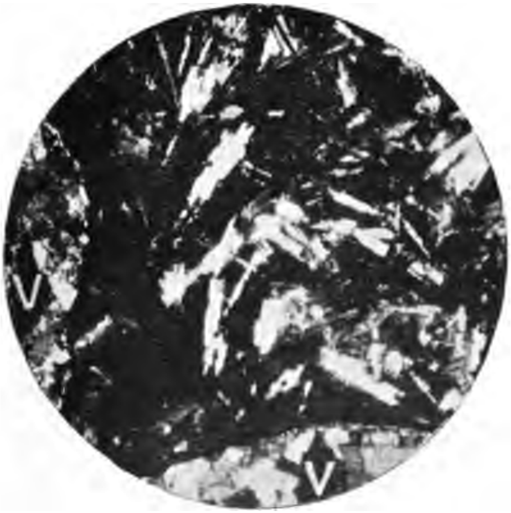

Photo: R. A. Farquharson. Neg. 1636.

$[\frac{1}{1122}]$ **The fine-grained epidotised basaltic dolerite, with quartz-epidote vesicles.**

The structure of the rock is fine plexal, and would be ophitic if granular augite were distinct. The structure is very similar to that in the dense black varieties of the Cue and Sandstone intrusive dolerite.

The rock is an epidotised and chloritised fine-grained, basaltic dolerite.

$[\frac{1}{1124}]$ near Mt. Herbert (see Fig. 43).

A fine-grained, greenish-black rock, with numerous small rounded vesicular carbonate forms and occasional small patches of yellow epidote.

S. The rock is very similar in section to $[\frac{1}{1122}]$, consisting of a fine-grained plexus of thin laths of felspar separated by dense granular dust of iron ore, in which granular and occasional platy epidote and zoisite, and small patches of green chlorite occur. There are, again occasional rounded vesicular forms as in $[\frac{1}{1122}]$, but in the present case, they are filled with calcite though usually with a border of granular epidote or zoisite. A few quartz and possibly albite grains also occur in the calcite. The tendency to a porphyritic development of the felspar as stout short laths is more pronounced than in $[\frac{1}{1122}]$, and the plexus is generally finer-grained. Interspersed through the iron dust is much opaque grey granular zoisite The chlorite most probably represents original augite. A very little quartz occurs, doubtless as a decomposition product.

The structure of the rock is finely ophitic.

The rock is a fine-grained, vesicular epidotised dolerite, with calcite vesicles. It is genetically connected with $[\frac{1}{1122}]$.

$[\frac{1}{1125}]$ near Mt. Herbert (see fig. 43).

A dull blackish-green, medium-grained rock, with numerous small, black chloritic patches in the lighter-green mass, and with occasional crystals of carbonate, and patches of yellow epidote.

S. The rock is considerably decomposed, but consists of a fine-grained plexus of obscure felspar laths, obscured by chlorite, numerous small opaque grey granular aggregates, and grains of iron ore, and containing large irregular green chlorite patches with associated yellow epidote grains and occasionally large plates of a carbonate more or less enclosed by the chlorite, and less distinct finely fibrous ragged hornblendic plates.

The felspar laths or rods are in part chloritised, in part kaolinised. The opaque grey grains consist of minute granular zoisite or epidote and have been derived from decomposition of the felspar.

The large chlorite and chlorite-carbonate patches appear to represent what were originally ferro-magnesian phenocrysts (augite), and the hornblende plates are doubtless altered forms of the same mineral. A curved or bent structure is noticeable in most of the hornblendic ragged plates, the result of dynamic strain.

Green chlorite often occurs in small patches interstitial to the felspar laths.

Rarely, a large rounded form is to be seen consisting of a border of green chlorite surrounding platy felspar obscured by fine scaly chlorite, and with platy granular epidote—a fact suggesting an origin as vesicles for some of the forms.

The structure is minutely ophitic or plexal, and the rock is a fine-grained, chloritised and epidotised dolerite, probably originally with augite phenocrysts.

$[\frac{1}{1081}]$ eight miles north-east of Depot Camp.

A fine-grained, dull greenish-black rock, with occasional blackish chloritic patches.

S. The rock is much decomposed, but consists of a very obscure plexus of zoisitised and chloritised columnar or lath-shaped felspars with pale green scales and patches of isotropic chlorite, grains and rods of epidote and zoisite, numerous small opaque grey granular zoisitic aggregates—the result of alteration of the felspar—and grains of ilmenite surrounded or replaced by leucoxene. Irregular grains of quartz occur sporadically in the sections, and there is doubtless a development of fine granular albite.

In this mass are occasional large rounded or occasional pale-green isotropic chloritic forms, with a border of radially extinguishing quartz plates round some rods and grains of zoisite. Whether these forms are vesicular infillings, or merely the alteration products of ferro-magnesian phenocrysts is not very clear, but their shape and composition seem to point to the former.

There are undoubted relics of a former ophitic structure.

The rock is a fine-grained, chloritic highly epidotised and zoisitised dolerite, now of somewhat indistinct character, owing to the advanced decomposition.

$[\frac{1}{1076}]$ 3½ miles east-south east of Camp 46, near Hughes Creek. Apparently a dyke intruding greenstone.

A liver-brown, fine-grained, basaltic rock, with numerous small and large rounded vesicular epidotic forms.

S. The rock is obviously considerably decomposed, but consists of a plexus of rods and laths of felspar separated by grains of iron ore, in part probably magnetite, in part altered to earthy haematite, and frequent patches of yellowish epidote composed of divergent curved radial needles. Most of the felspar occurs as small sharply outlined rods though stouter lath-shaped or columnar forms are not uncommon. The felspars in many cases are partially epidotised, and all are more or less kaolinised. Owing to the density and alteration of the iron ore, there is no trace of original ferro-magnesian, and it is quite possible that this rock facies originally contained none. The structure is finely ophitic.

The rock closely resembles the dense black almost porphyritic margins common in connection with the Sandstone dolerite, and also, so far as the rod-like felspars are concerned, the Bunbury basalt.

The rock is an epidotised and highly ferruginous basaltic dolerite, probably of volcanic origin.

$[\frac{1}{1077}]$ 2½ miles west of Ainslie Hill. Rock occurs in rounded boulders.

A very fine-grained, almost aphanitic liver-brown pebble. Some minute reflecting surfaces appear in places on the fractured surfaces.

S. The rock is extremely decomposed, and in consequence, the points of difference between various minerals are largely obscured. There appear, however, to have been phenocrysts of a twinned plagioclase and a ferro-magnesian in a ground-mass that consisted of long columnar platy and lath-shaped felspars, and ferro-magnesians in grains or small anhedral forms. All the felspars have been rendered turbid by kaolinisation and the ferro-magnesians are altered to fine scaly chlorite and reddish or brownish iron ores. Everywhere throughout the section there are sparse aggregates of thin acicular felspar laths such as occur in some fine-grained basalts. Some of the ferro-magnesian forms show no cleavage, and no crystalline margins, but are rounded, irregular and cracked, and may possibly represent olivine.

The structure of the rock is indistinct, but there appears to have been a felspar plexus in the mass with anhedral ferro-magnesian plates between the felspars, so that the structure may have been somewhat ophitic, or even somewhat porphyritic.

The rock, so far as can be made out, is a much altered, somewhat porphyritic basalt or basaltic dolerite. In some respects it resembles the doleritic or basaltic facies at Table Hill.

$[\frac{1}{1147}]$ about two miles north-north-east of Table Hill.

A dark brown, medium-grained rock with a reddish tint.

S. Consists of fairly large irregular platy crystals of colourless augite, and rarely of altered felspar in a ground made up of a fine plexus of small thin laths of felspar separated by granular chloritised augite. The large augite plates are all more or less cut up by interpenetrating felspar laths, and in some places the plates consist of detached fragments separated by the laths, but the optical continuity proves them to have been portions of the one plate. The augite in places has been altered to green isotropic chlorite, in some cases to a deep green chlorite resembling delessite.

Rarely, there is a large phenocryst of felspar obscured as to its optical characters by much micacisation and a certain amount of chloritisation. Olivine was not observed, unless represented by small round, brown-red, cracked chloritic forms. (Fig. 65.)

Fig. 65.

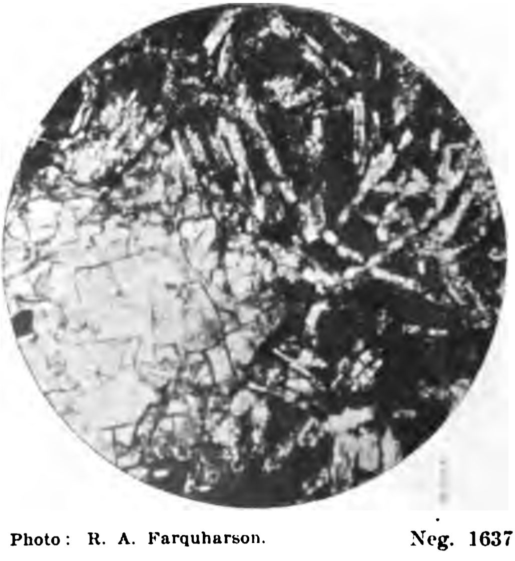

Photo: R. A. Farquharson. Neg. 1637.

$[\frac{1}{1147}]$ **The rather coarse micacised basaltic dolerite with an approach to porphyritic structure in augite and felspar crystals.**

The structure is finely ophitic, but there appear to be two generations in the felspar, and the platy augite cut into small fragments by the felspar laths gives an appearance of two generations in the augite, an appearance which is strengthened by the presence of some undoubted granular augite, though the augite plates lack crystal boundaries.

The rock is clearly a fairly coarse basaltic dolerite, with an approach to porphyritic structure, especially in the felspars.

$[\frac{1}{1148}]$ about 1½ miles north-north-east of Table Hill.

Similar in appearance to $[\frac{1}{1147}]$, but much finer in grain and with occasional apparently phenocrystal felspar crystals showing, as well as what appear to be small bluish quartz grains.

S. Obviously a fine-grained variety of $[\frac{1}{1147}]$, but with more pronounced porphyritic crystals of kaolinised felspar. The augite, however, is not in large interpenetrated plates, but in grains. The quartz grains are reserved for further investigation.

The rock is a fine-grained basaltic dolerite, stained brown-red by the oxidised iron of the augite.

$[\frac{1}{1149}]$ about a quarter-mile north-north-east of Table Hill.

A fine-grained, dark-red or brown rock, with numerous globular white spherules of quartz, some with a white quartz margin, and

Fig. 66.

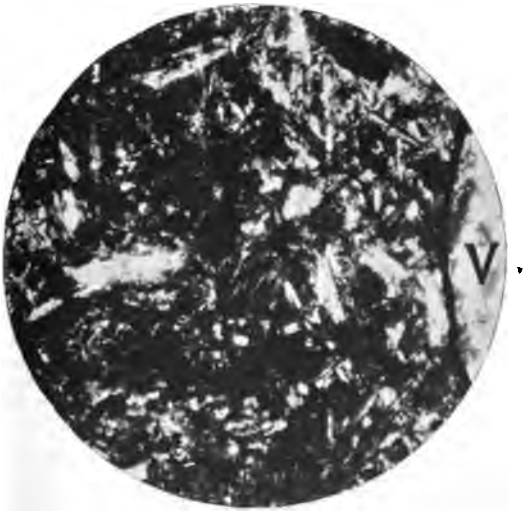

Photo: R. A. Farquharson. Neg. 1638.

$[\frac{1}{1149}]$ **Fine-grained ferruginous vesicular basaltic dolerite, with quartz vesicles and occasional felspar phenocrysts.**

an empty interior, others with the interior filled with pointed quartz crystals as in geodes, others filled entirely by white quartz.

S. The sections are obscured by a fairly dense granular dust of a brownish-black colour by incident light, but there appear a few phenocrysts of felspar and several circular quartzose vesicles in a fine-grained ground consisting of a loose plexus of thin felspar laths and minute hair-like needles of felspar. By higher powers, however, these latter are not so apparent and it is probable that they are the result of the brownish dust obscuring portions of the felspar laths. By high powers the plexus is wholly made up of the fine laths. In the ground are some fine scales of a micaceous character, but no definite trace of augite or any ferro-magnesian is observable. It is probable, however, that the small ferruginous aggregates in the slides represent what was formerly augite, especially as in [$\frac{1}{1148}$] much of the pyroxene was in course of alteration to brownish iron ore. The circular vesicles are seen to be composed wholly of quartz, a layer of fine columnar or fibrous plates with their length normal to the margins of the vesicle giving place towards the interior of the vesicle to a platy quartz-mass.

There is little doubt that these vesicular forms represent vesicles filled in subsequently by the quartz. (Fig. 66.)

The structure of the rock is that of fine-grained basaltic dolerites or augite-andesites with intersertal structure.

The original character of the rock, however, is not very clear, being much obscured by chemical decomposition. From the general character of the rock, the plexal character of the felspar, the probable ferruginous pseudomorphs after augite, the presence of rare felspar phenocrysts, and the similarity in appearance—except for the vesicular structure—between it and [$\frac{1}{1148}$], there is little doubt that [$\frac{1}{1149}$] represents a more altered and more pronouncedly volcanic facies of the same rock mass as [$\frac{1}{1147}$] and [$\frac{1}{1148}$].

[$\frac{1}{1150}$] Table Hill.

A pale yellowish-grey, fine-grained rock with faint reddish tinge.

S. Consists of a fine-grained plexus of thin closely twinned laths of felspar, with small indistinct grains of augite, some with schiller structure, the whole section obscured by opaque grey kaolinic material. Some patches are highly felspathic, with small tabular crystals of felspar enclosed in a mass of laths. An approach to the ophitic structure is noticeable in some cases, laths of felspar being partially enclosed by the augite grains. In some cases, too, highly twinned laths are so closely aggregated as to give rise almost to a feathery appearance. A pale pinkish tinge is noticeable in some of the pyroxenes. Some granular iron ore is scattered over the slide and some small patches of yellowish chlorite.

The structure of the rock is similar to that in [$\frac{1}{1148}$], and indeed the composition is also similar, but [$\frac{1}{1150}$] is more decomposed, (kaolinised) and resembles a bleached form of [$\frac{1}{1148}$]. In structure, too, it more closely approaches the volcanic as exemplified by certain basalts. There is little doubt, however, that the two rocks are genetically the same, being facies of the one rock-mass.

Moreover, though field evidence was unobtainable, there is, microscopically, good reason for concluding that the whole series is genetically connected, that it exhibits different facies of one rock-mass, and that the rock itself is of volcanic origin, and of basaltic dolerite type.

II.—DUNGE'S HILL-TOWNSEND RANGE SECTION.

Wilkinson Range Series.

[$\frac{1}{1037}$] one of a suite of specimens showing the variety of rocks in boulder-bed, Wilkinson Range.

A light grey, semi-translucent, quartz rock, composed of apparent grains of quartz with a few pinkish grains of felspar.

S. The rock consists chiefly of a mass of small rounded and subangular grains of quartz and slightly kaolinised felspar—chiefly orthoclase or microcline—enclosing much larger angular grains of quartz. In comparatively thick sections, the clastic character is more apparent than in thin sections. Quartz is by far the commonest constituent of the rock. Occasionally irregular extinction is visible in the quartz.

The rock is a felspathic quartzite or arkose.

III.—LAVERTON-DUNGE'S HILL SECTION.

Metamorphosed and Igneous Rocks.

1. **Greenstones.**

[$\frac{1}{1024}$] Mt. Sefton.

A fine-grained, dark-green, minutely acicular, and foliated hornblendic rock.

S. Consists of a dense mass of small rather ragged needles, rods or prisms of green pleochroic hornblende, all in more or less parallel alignment and interspersed with very minute grains and plates of clear albite, etc., arising from the disintegration of larger crystals of felspar. Some granular sphene occurs associated with the hornblende, and some of the crystals of the latter are partially chloritised. Irregular extinction is noticeable in some of the felspar plates.

The rock is a fine-grained acicular schistose epidiorite.

[$\frac{1}{1025}$] three-quarter mile north-east of [$\frac{1}{1024}$].

A dark grey-green, rather coarse-grained dioritic rock with evident shear structure.

S. Consists of numerous large very ragged plates and prisms as well as needles or long thin prisms of green hornblende, separated by more or less disintegrated columnar and platy felspars. The large hornblendic plates are obviously in course of disintegration to small scales, grains and thin prisms, and some have a distinctly fibrous structure especially at the margins.

The felspar columns and plates are also considerably broken down into small platy, granular and smaller columnar forms, and the resulting aggregates are often considerably obscured by grains, needles and prisms of green hornblende developed from the larger hornblende plates. In places the felspar is slightly kaolinised, and most of the forms exhibit irregular extinction and lamellation. Both albite and pericline lamellation are common. The species present appears to be fairly basic, at least as basic as andesine. Occasionally the hornblendic forms mould the felspars in a manner resembling the augite of ophitic dolerites.

Quartz, if present, is in only small amount.

There is a sensible parallelism in the alignment of the hornblendic plates.

The rock is a coarse-grained, sheared epidiorite or amphibolite, probably related to [$\frac{1}{1024}$].

2. Granite.

[$\frac{1}{1035}$] Point Uhr.

A medium-grained, pale-pinkish granite, consisting chiefly of quartz and pink felspar.

S. Consists of long platy crystals of microcline, orthoclase and a very acid plagioclase about oligoclase, plates of clear quartz and occasional flakes of greenish chloritic and brownish biotite. The microcline is generally fresh, with the characteristic twinning. The orthoclase and oligoclase are commonly turbid from kaolinisation and partial micacisation. There are inclusions both of the quartz and of the kaolinised species in the fresh unaltered microcline plates. A few grains of black iron ore (magnetite) are observable.

The rock is a medium to coarse-grained biotite-microcline granite.

[$\frac{1}{1036}$] Point Salvation.

A rather coarse-grained, dark-grey, granitic rock, with greyish or pinkish felspar crystals in a finer-grained mass, highly charged with scales of black biotite. The rock weathers to a yellowish tint.

S. Consists of occasional large irregular platy crystals of felspar surrounded by smaller platy and columnar crystals of felspar and plates of quartz, with scales and rods of brownish biotite, occasional ragged plates of green hornblende and some large and small grains of sphene. The larger felspar plates are in some cases untwinned, in others indistinctly lamellated, and at all times partially kaolinised. The species are difficult to determine, but appear to be in part orthoclase, in part an acid plagioclase. Some of the large plates enclose quartz grains. The finer-grained portions of the slides which enclose the large platy felspars consist of a mass of irregular plates of quartz, and twinned and untwinned plates and small columns of partially kaolinised felspar with flakes of the coloured biotite and hornblende and associated large grains of sphene. In addition to kaolinisation in the felspars, there is in places a certain amount of epidotisation.

The biotite is in long thin rods and short stout flakes, is brown coloured and strongly pleochroic. Small grains of green chlorite are noticeable and some of these appear to be altering to brownish biotite. The hornblende is green in colour and in places in process of alteration to green chlorite. Sphene is quite prominent in large and small wedge-shaped crystals, many of which have a pinkish or brownish tint.

There is evidence in the slides of mechanical deformation in the presence of irregular extinction in the felspar and quartz, and bending of some of the lamellae in some of the felspars.

The rock is a rather coarse-grained biotite-hornblende granite with a tendency to porphyritic structure. It differs from the preceding granite in the prevalence of biotite, the occurrence of green hornblende, the structure, the absence of microcline and the presence of a considerable amount of sphene. It is highly probable, therefore, that the two granites are not genetically the same. $[\frac{1}{1036}]$ possesses characters which suggest a closer resemblance to certain granodiorites than to granites.

APPENDIX B.

Reference List of Specimens Collected.

Reg. No.	Locality.	Determination.	Page in Bulletin.
$\frac{1}{1022}$	Manning Rock-Hole	Granite wash ..	
$\frac{1}{1023}$	One mile N.E. of Mt. Sefton ..	Porphyry	
$\frac{1}{1024}$	Mt. Sefton	Greenstone (epidiorite)	113, 195
$\frac{1}{1025}$	Mt. Sefton (¼-mile N.E. of $\frac{1}{1024}$)	Greenstone Cp. $\frac{1}{1024}$	113, 195
$\frac{1}{1026}$	Mt. Sefton	Greenstone	
$\frac{1}{1027}$	Two miles E. of Pt. Salvation	Sheared greenstone ..	113
$\frac{1}{1028}$	Tobin Hill	Greenstone ..	113
$\frac{1}{1029}$	Tobin Hill	Jasper Bar	113
$\frac{1}{1030}$	30 chains E. of Tobin Hill ..	Greenstone	113
$\frac{1}{1031}$	Dunge's Table Hill	Sandstone	
$\frac{1}{1032}$	Blackfellow Point	Claystone	
$\frac{1}{1033}$	"Lake country" between Camps 17 and 18	Travertine	
$\frac{1}{1034}$	Lake Yeo, near Camp 17 ..	Encrustations.. ..	112
$\frac{1}{1035}$	Point Uhr, near Camp 9 ..	Granite	113, 1[illegible]
$\frac{1}{1036}$	Point Salvation..	Granite	113, 1[illegible]
$\frac{1}{1037}$	Wilkinson Range	(Ice-borne boulders—variety of rocks)	109, 195
$\frac{1}{1038}$ $\frac{1}{1039}$	Three miles N.E. of Fetherstonhaugh Hill	Quartzite boulders ..	
$\frac{1}{1040}$	Two and a-half miles N.E. of Fetherstonhaugh Hill	Clayey Sandstone ..	
$\frac{1}{1041}$	Cassidy Hill	Porphyry	166
$\frac{1}{1042}$	Cassidy Hill (foot of)	Grit	100, 156
$\frac{1}{1043}$	Cassidy Hill (foot of)	Grit	100, 157
$\frac{1}{1044}$	Near Miller Hill	Greenstone	83, 131, 151
$\frac{1}{1045}$	Miller Hill	Porphyry	
$\frac{1}{1046}$	Near Miller Hill	Greenstone	83, 151
$\frac{1}{1047}$	Quarter mile E.S.E. of Warburton Cairn	Greenstone	
$\frac{1}{1048}$	Half-mile N.E. of Warburton Cairn	Greenstone (chlorite schist)	83
$\frac{1}{1049}$	Half mile S. of Camp 42 ..	Epidiorite	82, 131. 150
$\frac{1}{1050}$	Camp 42	Greenstone	
$\frac{1}{1051}$	One mile N.W. of Camp 42 ..	Greenstone	
$\frac{1}{1052}$	Two miles N. of Camp 42 ..	Quartz	
$\frac{1}{1053}$	Two and a-half miles N. of Camp 42	Porphyry	125, 164
$\frac{1}{1054}$	Five chains north of $\frac{1}{1053}$ ..	Porphyry	125, 165
$\frac{1}{1055}$	Five chains north of $\frac{1}{1054}$ ..	Porphyry	
$\frac{1}{1056}$	Three miles N. of Camp 42 ..	Boulder of lustre-mottled amphibolite	
$\frac{1}{1057}$	About 4½ miles N. of Camp 42	Sheared porphyry ..	86
$\frac{1}{1058}$	About 4½ miles N. of Camp 42	Pegmatite	

APPENDIX B.—*continued.*

Reg. No.	Locality.	Determination.	Page in Bulletin.
$\frac{1}{1059}$	About 4½ miles N. of Camp 42	Greenstone, and metamorphosed sediment	
$\frac{1}{1060}$	Five miles N.N.E. of Camp 42	Arkose	95, 177
$\frac{1}{1061}$	Hill, seven miles S.W. of Camp 43	Porphyry	86, 152
$\frac{1}{1062}$	30 chains S.W. of Camp 43	Granite	
$\frac{1}{1063}$	15 chains S.W. of Camp 43	Quartz dolerite	183
$\frac{1}{1064}$	"Spring Granite" (Camp 43)	Granite	86, 152
$\frac{1}{1065}$	One and a-half miles N. of Camp 42	Greenstone	
$\frac{1}{1066}$	One and three-quarter miles N.E. of Camp 43	Granite	86, 153
$\frac{1}{1067}$	Knoll near Camp 44	Granular porphyry	86, 154
$\frac{1}{1068}$	Five and a-half miles S.W. of Camp 44	Cp. $\frac{1}{1136}$	86, 152
$\frac{1}{1069}$	Six and a-half miles S.W. of Camp 44	Sheared garnetiferous porphyry	86
$\frac{1}{1070}$	Doubtful	Amphibolite	82, 98, 131, 149
$\frac{1}{1071}$ $\frac{1}{1072}$	Two and a-quarter miles N.E. of Camp 45	Granular porphyry	
$\frac{1}{1073}$	One and three-quarter miles N.E. of Camp 45	Schist	95, 176
$\frac{1}{1074}$	Half-mile S.W. of Camp 45	Porphyry	92, 125, 167
$\frac{1}{1075}$	Top of Hill one mile S.W. of Camp 45	Porphyry	
$\frac{1}{1076}$	Three and a-half miles E.S.E. of Camp 46	Basaltic dolerite (volcanic)	101, 191
$\frac{1}{1077}$	Two and a-half miles W. of Ainslie Hill	Basalt	101, 191
$\frac{1}{1078}$	Five miles N.E. of Depot Camp	Greywacke	100, 188
$\frac{1}{1079}$	Seven miles N.E. of Depot Camp	Calcareous grit	100, 188
$\frac{1}{1080}$	Seven and a-half miles N.E. of Depot Camp	Volcanic conglomerate	100, 137, 184
$\frac{1}{1081}$	Eight miles N.E. of Depot Camp	Dolerite	101, 190
$\frac{1}{1082}$	Near Cairn on Mt. Eveline	Porphyry	92, 125, 162
$\frac{1}{1083}$	Mt. Weir and neighbourhood	Various phases of the greenstone, and a specimen of porphyry	83, 150
$\frac{1}{1084}$	Six and a-half miles E. of Mt. Weir	Porphyry	165
$\frac{1}{1085}$	Five and a-half miles W. of Mt. Squires	Greywacke	94, 125, 136, 174
$\frac{1}{1086}$	Half-mile W. of Bob Hill	Felsophyre	92, 125, 169
$\frac{1}{1087}$	Bob Hill (near Mt. Squires)	Intermediate between granite and porphyry	92, 126, 169

APPENDIX B—*continued.*

Reg. No.	Locality.	Determination.	Page in Bulletin.
$\frac{1}{1088}$	Seven miles E.S.E. of Camp 49	Agglomerate and dolerite	94, 98. 99, 136, 174, 183
$\frac{1}{1089}$	Creek, one mile S. of Mt. Squires Cairn	Granite	92, 172
$\frac{1}{1090}$	Near Cairn on Mt. Squires ..	Micropegmatite ..	92, 171
$\frac{1}{1091}$	Camp 51 (E. of Mt. Squires) ..	Granite	92, 172
$\frac{1}{1092}$	Four and a-half miles N.E. of Camp 51	Granite	
$\frac{1}{1093}$	Cohn Hill	Granulite	
$\frac{1}{1094}$	Cohn Hill, E. of $\frac{1}{1093}$ ..	? Granulite	
$\frac{1}{1095}$	Cohn Hill, E. of $\frac{1}{1094}$ ..	Granulite	87, 159
$\frac{1}{1096}$	Cohn Hill, E. of $\frac{1}{1095}$ ..	? Granulite	87, 90
$\frac{1}{1097}$	Lightning Rock	Granite	155
$\frac{1}{1098}$	Camp 53, Cavenagh Range ..	Olivine norite ..	132, 178
$\frac{1}{1099}$	Fort Welcome, Cavenagh Range	Olivine norite ..	97, 132, 178
$\frac{1}{1100}$	Fort Welcome, Cavenagh Range	Basaltic dolerite ..	97, 98, 99, 183
$\frac{1}{1101}$	Fort Mueller, Cavenagh Range	Norite	132, 179
$\frac{1}{1102}$	Six and a-half miles N.E. of Fort Mueller	Porphyry	91, 127, 166
$\frac{1}{1103}$	Hill, 2½ miles W. of Camp 55 ..	Metamorphic quartzite	95, 175
$\frac{1}{1104}$	Camp 55 (Barnard Rocks) ..	Granite	95, 157
$\frac{1}{1105}$	Hill, one mile E. of Camp 55	Agglomerate	95, 176
$\frac{1}{1106}$	One mile E. of Camp 55 ..	Porphyrite	91, 127, 166
$\frac{1}{1107}$	Camp 56 (E. end of Blackstone Range)	Olivine norite ..	132, 180
$\frac{1}{1108}$	About four miles W.S.W. of Camp 57	Granite	157
$\frac{1}{1109}$	About four miles W.S.W. of Camp 57	Dolerite	98, 99 184
$\frac{1}{1110}$	About four miles W.S.W. of Camp 57	? Granite	
$\frac{1}{1111}$	Near Cairn on Mt. Aloysius ..	Granulite	89, 161
$\frac{1}{1112}$	One and a-half miles W.S.W. of Mt. Aloysius Cairn	Gneiss	89, 90, 162
$\frac{1}{1113}$	Amy Giles Rocks	Granite	157
$\frac{1}{1114}$	Seven and a-half miles W. of Camp 59	Gneiss	89, 162
$\frac{1}{1115}$	Camp 59 (near Mt. Gosse) ..	Granite	90, 128, 158
$\frac{1}{1116}$	One mile E. of Mt. Scott ..	Granite	128, 155
$\frac{1}{1117}$	Mt. Scott	Granite	128, 156
$\frac{1}{1118}$	Frank Scott Hill	Greenstone (epidiorite)	84, 131, 152
$\frac{1}{1119}$	Four miles W. of Lightning Rock	Quartz dolerite	181
$\frac{1}{1120}$	Two miles N.E. of Frank Scott Hill	Conglomerate ..	100, 137, 185
$\frac{1}{1121}$	Five and a-quarter miles N. of Depot Camp	Calcareous grit * ..	100, 185

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* See Fig. 43.

APPENDIX B—*continued.*

Reg. No.	Locality.	Determination.	Page in Bulletin.
$\frac{1}{1122}$	Near Mt. Herbert	Basaltic dolerite * ..	101, 135, 189
$\frac{1}{1123}$	Near Mt. Herbert	Greenstone *	131, 151
$\frac{1}{1124}$	Near Mt. Herbert	Vesicular dolerite * ..	101, 135, 190
$\frac{1}{1125}$	Near Mt. Herbert	Dolerite *	101, 135, 190
$\frac{1}{1126}$	Near Mt. Herbert	Porphyry *	
$\frac{1}{1127}$	Near Mt. Herbert	? Greenstone * ..	
$\frac{1}{1128}$	Three-quarter mile N.N.W. of Camp 67	Porphyry	92, 167
$\frac{1}{1129}$	One and a-half miles N.N.W. of Camp 67	Granular porphyry ..	92, 168
$\frac{1}{1130}$	Four and a-half miles N.N.W. of Camp 67	? Granular porphyry	
$\frac{1}{1131}$	Six miles W.S.W. of Camp 68	Granite	86
$\frac{1}{1132}$	Gnamma-hole, 3¼ miles W.S.W. of Camp 68	Granite	86, 153
$\frac{1}{1133}$	Bentley Hill	Granite	86, 154
$\frac{1}{1134}$	Seven miles S. of Camp 69 (Bentley Hill)	Granite	87, 155
$\frac{1}{1135}$	Seven and three-quarter miles S. of Camp 69	Olivine dolerite ..	182
$\frac{1}{1136}$	Three and a-half miles N. of Mt. Waugh	Granular quartz-porphyry	86, 152
$\frac{1}{1137}$	One and three-quarter miles S.W. of Mt. Waugh	Greenstone (amphibolite)	82, 148
$\frac{1}{1138}$	Half-mile S.W. of $\frac{1}{1137}$ ..	Greenstone	82, 149
$\frac{1}{1139}$	Two miles N.N.E. of Kathleen Hill	Porphyry	91, 106
$\frac{1}{1140}$	Kathleen Hill, near Mt. Eveline	Porphyry	91, 125, 164
$\frac{1}{1141}$	Mt. Shaw	Porphyry	
$\frac{1}{1142}$	Two and a-quarter miles W.S.W. of Camp 65	Porphyry	
$\frac{1}{1143}$	Two and three-quarter miles W.S.W. of Camp 65	Porphyry	
$\frac{1}{1144}$	Eight miles W.S.W. of Camp 65	Cp. $\frac{1}{1082}$	92, 173
$\frac{1}{1145}$	Six miles W.S.W. of Camp 65	Porphyry	92, 124, 173
$\frac{1}{1146}$	Townsend Range, near Depot Camp	Quartzite	101, 188
$\frac{1}{1147}$	Two miles N.N.E. of Table Hill	Basaltic dolerite (volcanic)	192
$\frac{1}{1148}$	One and a half miles N.N.E. of Table Hill	Basaltic dolerite (volcanic)	193
$\frac{1}{1149}$	Quarter-mile N.N.E. of Table Hill	Cp. $\frac{1}{1147}$ and $\frac{1}{1148}$ ..	193
$\frac{1}{1150}$	Table Hill	Basaltic dolerite (volcanic)	194
$\frac{1}{1151}$	Table Hill	? Basaltic dolerite ..	
$\frac{1}{1152}$	Near Depot Camp	Travertine	
$\frac{1}{1153}$	Pt. Saunders Breakaways ..	Pebbles from Boulder-bed	

* See Fig. 43.

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Geological Map of Kalgoorlie: by A. Gibb Maitland and W. D. Campbell. Scale, 10 chains per inch. Six sheets. Price, 21s. 1902.

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Geological Sketch Map of Western Australia: by A. Gibb Maitland. Scale, 1/1,584,000. Four sheets.

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Notes on the Greenbushes Tinfield; Boring for Water at Mulgarrie; Boring for Water at Hayes' New Find; the Geology of the Bardoc District; On the Development of Mining in the locality of Donnybrook; The Geology of the North Lead, Kanowna; The Kanowna Great Boulder, G.M.L. 885x; Mineral Waters; Composition of Native Gold; Greenbushes Tin Ore; Cobalt Ores; Menzies Goldfield; Kalgoorlie Goldfield; Coolgardie Goldfield. Price, 1s. 1900.

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Annual Progress Report for the Year 1914, containing—
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Annual Progress Report for Year, 1916, containing—
Notes on the Yalgoo Goldfield; Notes on a portion of the South-West Division; The occurrence of Molybdenite at North Dandalup; The Graphite Deposits at Kendenup and surrounding Districts; The Koolyanobbing Iron Ore Deposits; Westonia. Expedition to the Warburton Ranges and the South Australian Border; Comet Vale; Warriedar; Jasper Hill, Murchison Goldfield; Quinn's, Murchison Goldfield. Price, 1s. 1917

III.—BULLETINS.

I. Bibliography of the Geology of Western Australia: by A. Gibb Maitland, Government Geologist. Price, 1s. 1898.

II. The State of Mining in the Kimberley District, and the probability of obtaining Artesian Water between the Pilbara Goldfields and the Great Desert: by R. Neil Smith. *(Out of print.)* 1898.

III. The Coolgardie Goldfield: by Torrington Blatchford, Assistant Geologist. Price, 1s. 1899.

IV. The Mineral Wealth of Western Australia: by A. Gibb Maitland, Government Geologist. Price, 1s. 1900.

V. The Phillips River Mining District: by Torrington Blatchford, Assistant Geologist. Price, 1s. See Bulletin XXXV. 1900.

VI. Notes from the Departmental Laboratory: by E. S. Simpson, Mineralogist and Assayer. *(Out of print.)* 1902.

VII. The Auriferous Reefs of Cue and Day Dawn: by W. D. Campbell, Assistant Geologist. Price, 1s. See Bulletin XXIX. 1903.

VIII. Lennonville, Mount Magnet, and Boogardie, Murchison Goldfield: by C. G. Gibson, Assistant Geologist. Price, 1s. 1903.

IX. The Northampton Mining District: by A. Gibb Maitland, Government Geologist. Price, 1s. 1903.

X. Palæontological Contributions to the Geology of Western Australia. I. Carboniferous Fossils from the Gascoyne District: by R. Etheridge, Jun. Price, 2s. 1903.

XI. The Country between Edjudina and Yundamindera, North Coolgardie Goldfield: by A. Gibb Maitland, Government Geologist. *(Out of print.)* 1903.

XII. Mulline, Ularring, Mulwarrie, and Davyhurst, North Coolgardie Goldfield; by C. G. Gibson, Assistant Geologist. Price, 2s. 1903.

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XIV. A Part of the Murchison Goldfield: by C. G. Gibson, Assistant Geologist. *(Out of print.)* 1904.

XV. Preliminary Report on the Pilbara Goldfield: by A. Gibb Maitland, Government Geologist. *(Out of print.)* For reprint see Bulletin XL. 1904.

XVI. Mineral Production of Western Australia up to 1903: by A. Gibb Maitland, Government Geologist, and C. F. V. Jackson, Assistant Geologist. *(Out of print.)* 1904.

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Bulletins—*continued.*

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XLI. **The West Pilbara Goldfield**: by H. P. Woodward, Assistant Government Geologist. (*Out of print.*) 1911.

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L. **The Geology and Mineral Industry of Western Australia**: by A. Gibb Maitland and A. Montgomery. Price, 2s. 6d. 1912.

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LXXIV. Miscellaneous Reports, Series V., No. 61–68. 1917.

LXXV. A Geological Reconnaissance in the country between Laverton and the South Australian Border, including part of the Mt. Margaret Goldfield. 1918.

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In the Press.—LXX. The Western Australian Mining Handbook: edited by A. Gibb Maitland, Government Geologist.

In preparation:—

The Geology and Mineral Resources of the Maritime Districts on the South-West Division (Limes Cements, Clays, etc.): by H. P. Woodward, Assistant Government Geologist.

The Mining Geology of Niagara, Kookynie, and Tampa, North Coolgardie: by J. T. Jutson, Field Geologist.

The Artesian Water Resources of Western Australia: by A. Gibb Maitland, Government Geologist.

The Magnesite Deposits of Western Australia, by F. R. Feldtmann.

The Mining Geology of Comet Vale and Goongarrie, by J. T. Jutson.

The Mining Geology of the Yalgoo Goldfield, by A. Gibb Maitland, Government Geologist.

IV.—MEMOIRS.

In preparation:—

1. **The Geology and Mineral Resources of Western Australia: by A. Gibb Maitland.**

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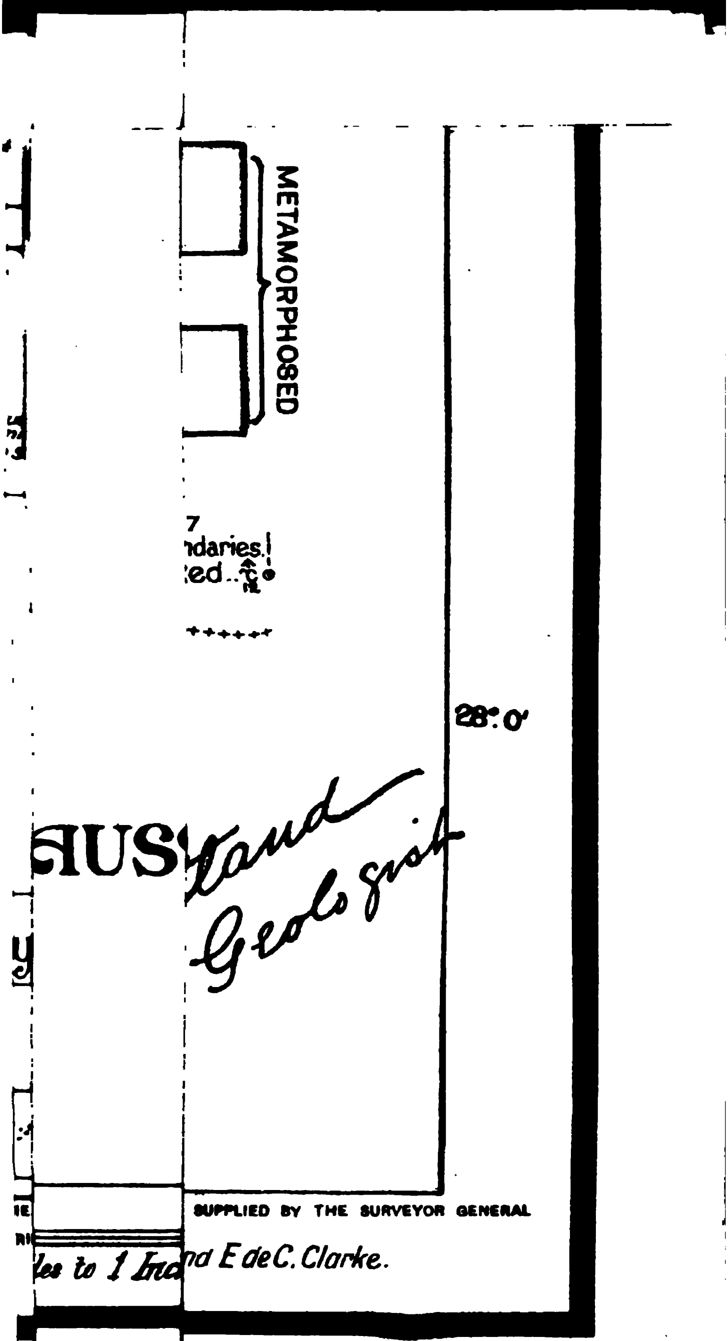

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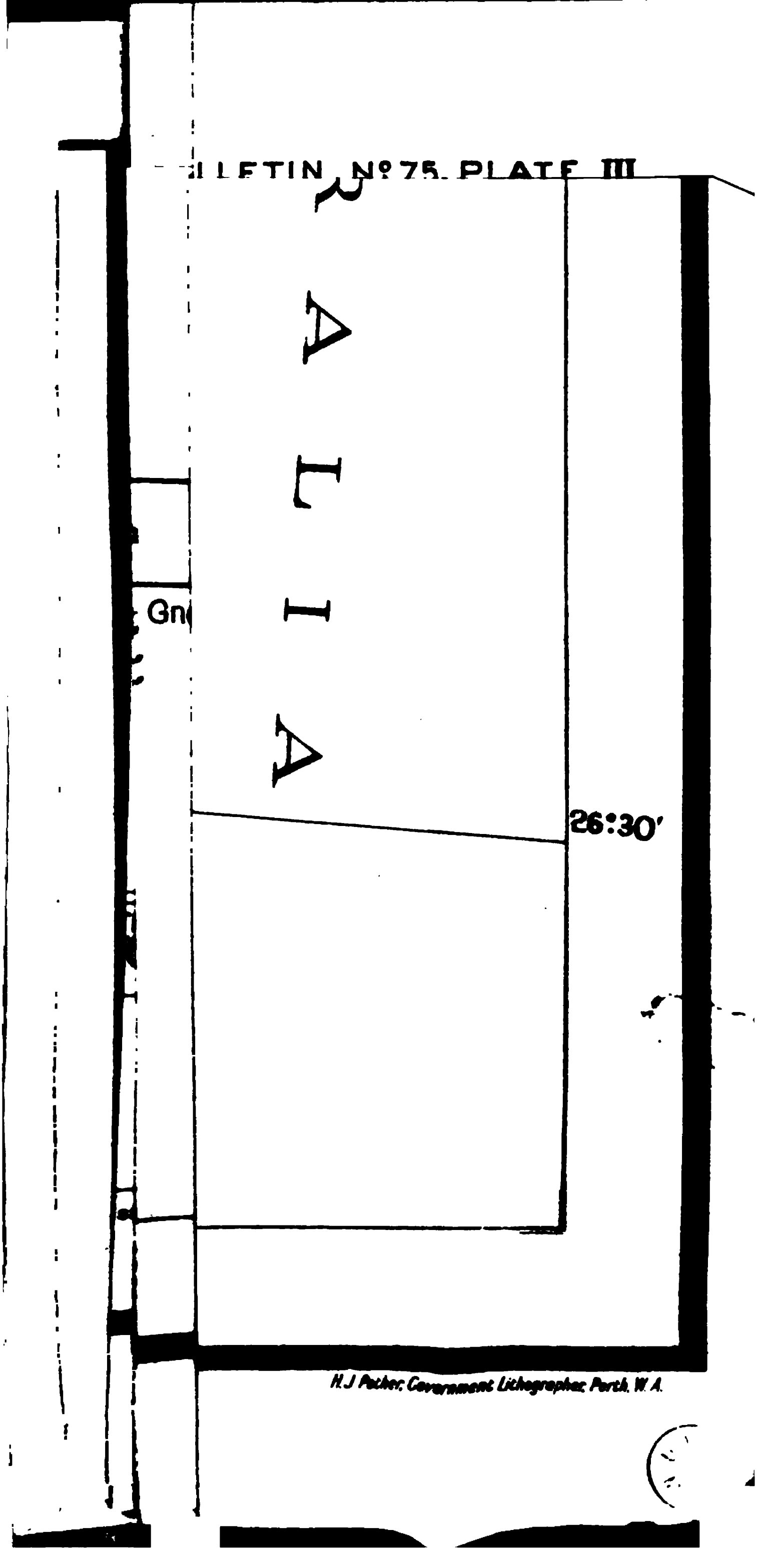

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WESTERN AUSTRALIA.

GEOLOGICAL SURVEY.

BULLETIN No. 75.

A
Geological Reconnaissance
OF THE
Country between Laverton
AND THE
South Australian Border
(near South Latitude 26°),
Including part of the
Mount Margaret Goldfield,

BY

H. W. B. TALBOT and E. de C. CLARKE,
Field Geologists.

Petrology by R. A. FARQUHARSON.

ISSUED UNDER THE AUTHORITY OF
THE HON. R. T. ROBINSON, K.C., M.L.A., MINISTER FOR MINES.

WITH SIX PLATES AND SIXTY-SIX FIGURES.

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